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Presidential Address.

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PROCEEDINGS
OF THE
FORTY-FOURTH SESSION
CALCUTTA-1957

PART II
PRESIDENTIAL ADDRESSES

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Proceedings of the Forty-fourth Indian Science Congress

PART II : PRESIDENTIAL ADDRESSES

CONTENTS

PAGE

ADDRESS OF THE GENERAL PRESIDENT—Dr. Bidhan Chandra Roy 1

Sectional Addresses

I. MATHEMATICS : *Functional Equations and Dirichlet Series* —Prof. K. Chandrasekharan 11

II. STATISTICS : *Statistical Methods in Psychometric Research* —Dr. P. K. Bose 20

III. PHYSICS : *Semi-Conducting Cuprous Oxide* ... ... —Prof. K. R. Dixit 51

IV. CHEMISTRY : *India's Contribution to Inorganic Chemistry* —Prof. S. M. Mehta 61

V. GEOLOGY AND GEOGRAPHY : *Geological Surveys and Mineral Explorations in National Planning*—Dr. B. C. Roy 71

VI. BOTANY : *Air Pollution in Relation to Plant Diseases*— Prof. S. N. Das-Gupta 88

VII. ZOOLOGY AND ENTOMOLOGY : *A New Approach to Helminthology in India*—Prof. M. B. Lal 108

VIII. ANTHROPOLOGY AND ARCHAEOLOGY : *Caste in Modern India*—Shri M. N. Srinivas 123

IX. MEDICAL AND VETERINARY SCIENCES : *Medical Research in India*—Dr. C. R. Das Gupta 143

X. AGRICULTURAL SCIENCES : *The Phenomena of Insect Parasitism and their Practical Utilisation in the Biological Control of Insect Pests*—Dr. E. S. Narayanan ... 167

XI. PHYSIOLOGY : *Some Theoretical and Applied Aspects of the Physiology of Unstriated Muscle*—Dr. Inderjit Singh ... 190

XII. PSYCHOLOGY AND EDUCATIONAL SCIENCES : *Place of Psychological Tests in Vocational Guidance*—Dr. S. M. Mohsin 197

XIII. ENGINEERING AND METALLURGY : *Metallurgical Research and Education*—Dr. G. P. Chatterjee 209

FORTY-FOURTH INDIAN SCIENCE CONGRESS

CALCUTTA, 1957

Congress President : DR. BIDHAN CHANDRA ROY, M.D., M.R.C.P., F.R.C.S. (Eng.), D.Sc. (Cal. & All.).

PRESIDENTIAL ADDRESS

MR. PRIME MINISTER, DELEGATES AND FRIENDS :

I extend my cordial greetings to the distinguished scientists who have gathered here today, as they do every year, to exchange notes regarding the latest discoveries in the various fields of their search after truth. The Indian Science Congress Association meets annually with the main object of discussing how best the latest researches and investigations in science could be utilised for the promotion of human welfare in general and for the development of the country.

We are meeting at a time when we have successfully completed the First Five Year Plan in India and have just started on the Second Plan. For the implementation of a Plan of this magnitude we would need the services of many more scientists, many more engineers, many more physicists and many more technologists than are available in the country at present for its rapid development in various directions. The more we come to appreciate the latest developments in science and their application to human welfare, the more we begin to realise that while material resources are no doubt a fundamental requirement for the successful development of the country, we depend no less upon human resources. Moreover, it is not merely the technical knowledge, which one may possess that will help in his task, it is equally essential that there must be developed ability to apply this knowledge to the organisation and development of industries and to the production of means of human welfare. There is, moreover, the need for adaptation. We might get technical knowledge from other more advanced countries, but the scientists of India should be able to adopt this technical knowledge to the needs of the country, so that it may be effectively operative under different climatic and environmental conditions and for utilisation of indigenous raw materials. It is, therefore, not enough to borrow from other countries the results of their researches ; we should be able to undertake original researches ourselves and adapt the results of such researches to the conditions obtaining in our own country. Such researches would be a continuous, and, no doubt, an arduous process too. Without it no progress can be achieved in this competitive world.

In this country we have been doing research in scientific subjects for the past 40 years or so, but we have not achieved much in engineering and technological research, namely, research in design, research in development of machinery or its manufacture, erection and maintenance. For an underdeveloped country like India, it is not only essential that we should ourselves be able to manufacture machinery and build up factories, but we should also know how to do it with the materials that we possess. Engineering research does not merely mean the application of physics to engineering problems, but it also includes such new lines of advancement in engineering as biological and chemical engineering and public health engineering, which have definite social values, as they deal with problems which affect the common man. Development in these lines can be achieved only through patient and persistent research. Other countries have done so and have gone ahead, and we in this country should not delay in utilising whatever resources we possess for the development of engineering in these directions. Steps taken towards this end may even mean our taking some amount of financial risk, but this is worth doing. Human mind ordinarily follows a particular groove and does not easily adapt itself to new ideas. Scientists would indeed be doing a great service to society if they would demonstrate to the common man the value of quickly adapting and utilising the results of new researches.

A glance at the Second Five Year Plan will reveal that quite a large number of development schemes have been included which would involve such huge cost that we may find it difficult to implement them unless our engineers and technicians are able to find effective and yet cheaper methods of executing these projects. Experience has shown that through scientific methods raw materials may be produced more cheaply and abundantly. Therefore, we have to secure the help of scientists to make available to us cheaper raw materials. In this country, we possess a vast potential of man-power, which we may be able to utilise and thus lower the total cost considerably. But that would mean that the designs of construction and the methods involved should be such that without much specialised skill the common man may be able to easily understand these, and take his full share in executing them. Take, for instance, the building of houses for the large number of our people who live in the city slums or in the rural areas. If the usual plan of the professional architect is followed, it would entail skilled processes and heavy expenditure so much so that the projects may become prohibitive. On the other hand, if the plans and designs for construction are simplified and locally available materials are utilised, even ordinary individuals may be able to give their helping hand in building their own houses and the total cost may be made considerably cheaper.

Sometimes I am inclined to envy the votaries of science, who like yourselves, devote their whole time, energy and intellect to discovering something new. It was not given to me to devote myself exclusively to the pursuit of science and to unravel the mysteries of life. When I was a young student of science, I had learnt that "Matter is indestructible". Since then as a medical practitioner, it has been my lot to face life under varied conditions, and I have also been a witness to hundreds of deaths. I have often wondered what gives life its versatility—what it is that makes one person so different from another. On the other hand, I have also wondered what the lifeless body signified. Matter, says the scientist, is indestructible, and yet, I ask what happens to the dead body, which is composed of matter, after it is buried under the earth or consigned to the flames? What becomes of the matter composing the body? Obviously it changes its character. The elements of which a body is composed get diffused to the four corners of the earth and get mixed up with similar and other elements. The process indicates a transmutation of the basic elements of the human body. The conclusion is inevitable that the fundamental elements composing the human body change their characteristics or form but they are not destroyed. It is yet a mystery as to what extent an individual when dying releases forces which consciously or unconsciously go on affecting generations of human beings that follow him. From science I was drifting into the field of mysticism or perhaps spirituality.

History tells us that in the last 2,500 years, 902 wars have been fought, 1,615 internal dissensions have taken place, which have rent nations asunder. The most bellicose period of the world history has been the first half of the 20th century. We are now in the midst of a new Era, call it the Atomic Age. Science has found a new and a vast source of energy which has put into man's hands great power, for good or for evil. Whether the hydrogen bomb will prove to be the doom of mankind, or a stabilising force for permanent peace cannot yet be predicted. On the other hand, it is also true that materials developed from Nuclear Reactors can be wholly beneficient. They create a host of new substances, mainly radioactive, which are proving to be of the greatest value in research, medicine, agriculture and industry and one day, perhaps very soon, we will have these Reactors which will be used in atomic power plants which will make available new sources of energy by using fissionable materials as fuel. This fuel will not only be highly concentrated but will be easily transportable to countries where coal may be scarce or oil may not be available or even water power may not have been developed.

Will peace prevail as civilisation advances? At least history lends no support to this belief. Man has been getting more civilised and yet discovering more and more desetructive weapons of killing. Violence is not known to have given a quietus to violence. No war has been able to end all wars. The last two world wars revealed another distressing feature: during hostilities the peaceful citizen was as much a victim of hostile action as a combatant at a military establishment. Wars have today assumed a totalitarian character. The development of guided missiles may mean destruction of whole cities, of districts, and countries from sources thousands of miles away—and, may destroy everything contained therein, the unarmed citizens' houses and farms, schools, hospitals and places of worship, the sources of food and water. Were the scientist and the technologist, who created the machinery of war, the witting or the unwitting instruments of military leaders, or were the scientists merely chips drifting along in the turbulent stream over which they had no control? We know that the one pursuit of the physicist and chemist is the discovery of the nature of matter and energy; the one purpose of the technologist is to apply that energy in changing the social environment; and, the one purpose of the capitalist is to make profits through that energy. Thus both industry and war have provided the momentum which ever increases the output of energy. But can the scientists be held responsible for this perversion of physics and chemistry? It is not he who declares war; nor it is he who leads the armies. Yet he has been as direct an aid to military States as if he had been commanded to make discoveries of military importance. This is because his problems are given to him by a society in arms of a Militant State.

Scientists and engineers of the 15th, 16th and 17th centuries were aware of their relation to the Military State. Leibnitz, Denis Papin, Otto Von Guericke and others dabbled in military mechanics. Leonardo offered his services to the Duke of Milan, primarily as a military engineer; Galileo was a Professor of Military Science. Voyages to the undiscovered India, America and Africa created a demand to determine the position of the ship in an unchartered sea. The classic studies of magnetism made by William Gilbert, in the 17th century, followed the observation of mariners on the vagaries of the compass-needle. Roger Bacon and Berthhold Schwarz, mere monks, are credited with the discovery of a simple mixture, which was gunpowder. All explosives from gunpowder to Trinitrotoluene were developed by civilians.

And, yet, it is science which has been the cementing agency betweeen peoples of different races, religions, traditions and customs. When a whole population uses a common railway system, and telegraph and telephone links, or listens to music and speeches radiating from a common broadcasting station, or thrills at the same cinematographic film projected at a thousand theatres simultaneously, or rides to and from work in common carriers like omnibuses and tramcars, or wears standardised garments and shoes, there results a sense of unity. Then science becomes an agency that draws millions of people into one common fabric of human society or social order.

We are here presented with a paradox. Science and technology are essentially international in spirit. By training, these principles can be inculcated anywhere. But the industrial fruits of science and technology are governed by economic or military factors. While scientific progress sometimes takes place because of the constant internal urge of the physicist, chemist and technologist to seek newer objects of research, the greatest stimulation to such progress has been dictated by the economic needs of a country or the exigencies of war. This mobilisation of science and technology has made it impossible for the small and technologically backward nations to wage mechanised wars without external assistance. The dread of finding itself cut off from food supplies and industrial materials develops an instinct of self-preservation in a country. It strives to have a type of nationalism which wants to secure raw materials for the country's safety and production. Thus one country's desire spells another country's danger. A country cannot but retain what it has gained and struggle for more. The type of nationalism which develops in the country is economic or political in spirit and the citizen becomes the member of an industrial and military State.

During the last twenty years, scientists have slowly awakened to this abuse of their talents and discoveries. They have seen as much misery flow out of the misapplication of their work as out of war. They now crave for the opportunity to improve the quality of the human stock through the wider support and application of Eugenics: They dream of producing synthetic substitutes of meat, milk and eggs; they hold out the promise of a world in which poverty and misery will be unknown. They maintain that in the past, science had been compelled to pursue an irrational course, which had little relation to the realities of life.

Today, through science, wherever physical expansion of an area is not possible, new means of crop production and new industrial methods are discovered, which go to create the wealth necessary to raise the standard of living and banish the spectre of unemployment. These are brought about through painstaking researches. The stuff of which the Universe is composed is being torn apart, molecule by molecule, atom by atom, and out of the atomic fragments new kinds of matter are being created and new energy is being released.

To nine persons out of ten, the chemist is still something of a magician, a mysterious figure, impelled to mix together strange and sometimes dangerous substances, only to discover that he has at his command, an explosive that will blast mountains or a plastic that can be a substitute for any known material of common use. It is so with the technological chemist, the metallurgical chemist, the nutritional chemist, the chemist who manufactures synthetic foods and artificial dress materials like rayons and nylons and plastics. Today we are in the throes of a Chemical Revolution.

Synthetic chemistry cannot ignore the progress made in "chemotherapy", to which I wish to make a reference in detail. Paul Ehrlich, who coined this term, limited it to the chemical treatment of bacterial diseases ; but today pharmachologists are inclined to describe Chemotherapy as that branch of science which deals with chemical effects of drugs on living organisms. They include among the chemotherapeutic agents hormones, vitamins, pain-killers, sleep producers and a host of such substances. Even quinine from Peruvian bark, extracts from toads and cobra venom, which affect the nerves and stimulate the heart, belong to the same category. The story of scientific chemotherapy, a subject which is of great interest to me, starts with Ehrlich's classical study of Syphilis. Ehrlich discovered that certain dyes, derived from Napthalene, would only stain the germs inside the tissues which themselves remained unstained. This gave Ehrlich the cue to the discovery of a germicide which would attack the microbes and yet leave the animal tissues unaffected. He knew that many tropical diseases like Kalazar, Sleeping Sickness, Dysentery were caused by Protozoa. Sleeping Sickness, endemic in Africa, was caused by a protozoa called Trypanosome. After patient and laborious research, Ehrlich found a harmless chemical which would seek out a germ in the tissues. To this chemical was to be attached a killer which would destroy the bacteria. Arsenic was found to be such a killer. By repeated experiments he succeeded in combining arsenic with a selective organic compound. When Schaudin discovered that Syphilis was caused by a protozoa called Spirochete, he also discovered that Spirochete and Trypanosome were similar in nature. With this knowledge in his possession Ehrlich found an organic compound, 914 Neoarsphenamine, which could be injected to cure Syphilis which had till then been a menace to society.

The medical world was electrified by Ehrlich's success. If Syphilis could be treated by chemotherapy, why not a lot of other infectious diseases caused by "Cocci" and by "Bacilli"? Streptococci, Staphylococci, Gonococci, Menigococci and Pneumococci, which cause widespread infections and devastation among human beings could be treated in a similar manner. Chemists working in Farben Industry experimented with "Azo" dyes and found them useful for blood infections by Streptococci. They called this drug Prontosil.

While these new discoveries regarding chemotherapeutic drugs were being made, Dr. Dabos of the Rockefeller Institute for Medical Research extracted a powerful germicide from the soil which healed the wounds of Empyma, Carbuncle, boils and ulcers. He wondered how the soil which itself is full of deadly germs manages to produce plants in abundance, how the disease germs which kill a man are themselves killed when he is buried? Evidently the soil is self-cleaning. This finding was interesting and Dabos found a chemical Tyrothricin in the soil which killed the germs. An accident, however, led to the discovery of a chemotherapeutic agent more powerful than Tyrothricin. The discoverer was Sir Alexander Flemming and what he discovered was Penicillin. Flemming was growing some Staphylococci in Petri dishes and he noticed that in some places the Cocci were not growing. Spots of green mould had appeared in these places. In September 1928, Flemming made cultures of the green mould, which he found to be a variety of Penicillium and he called the pure culture Penicillin—an ideal chemotherapeutic agent. Such moulds generally grow on cheese, on trees and on the soil, which we in our ignorance have regarded as useless, if not dangerous. Some more research work had to be done before Penicillin could be made available for Therapeusis. In 1939, Dr. Florey discovered that in body secretions, i.e., tear, saliva and in eggwhite there was an enzyme (Lysozyme) which dissolved bacteria. (No wonder animals lick their wounds.) He studied Penicillin from various aspects and produced it in sufficient quantities in a purified form for clinical use. There are now 100,000 type moulds which can yield antibiotics.

Thus with the arsenical compounds used in treating Syphilis, with the Sulfa drugs, with Tyrothricin, and lastly with Penicillin and allied antibiotics we have an array of chemotherapeutic drugs available to save mankind from the ravages of microbes. Such researches only prove that the human body is a delicately balanced chemical apparatus. Destroy that balance and we fall sick. To cure a disease chemical balance must be restored. Poison must fight poison. One such poison in the human body is Insulin, which controls the utilisation of sugar in the body, another is Adrenalin which is a valuable drug in haemorrhagic conditions. The Vitamins and Hormones about which we hear so much also act as chemotherapeutic agents, and they direct metabolism in the human body. We often wonder why we get old. It is because the body's chemistry has changed. Turn where we will within us and we discover chemicals at work. Therefore, the development of chemotherapy is part of the chemical revolution that is changing life and industry.

Ever since the days of Charles Darwin physiologists and anatomists have had their doubts as to how long primitive savage man will survive the nervous strain of machine world where he lives an artificial life in artificial environment. At a recent Congress of the American College of Surgeons, Dr. Buerki, President of the American Hospital Association, presented a picture of a modern man, a victim of high blood pressure, enlarged heart, failing circulation, jangled nerves, result of doing several things at the same time. At Yale, the Nobel Prize winner Sir Joseph Barcroft showed how delicate is the balance between mind and body and how quickly the mind succumbs when the conditions under which the body naturally thrives are only slightly changed. In 1936, at the meeting of the British Association for Advancement of Science, Prof. Hawkins, the distinguished Palaeontologist said that man was the 'only irrational creature'.

The glory and the curse of the man is his Brain. While it raises him above the beasts, it dooms him as a species, for the brain is getting over-developed and over-specialised. It endows him with a mind that conceives new machines to take the place of muscles, new instruments to supplement inadequate senses, new and complex ways of living in communities. The poor body cannot adapt itself rapidly enough to the social and technological changes conceived by the mind. Heart and muscle belong to the jungle, the modern mind of man has an environment of its own creation. The verdict appears to be that man must crack under this strain.

It is the simple organism that endures. The one celled organism—Amoeba—endures best of all. The lowly things are harmonious wholes; introduce complexity and specialisation, the old harmony is impaired. Man is developed from simpler species, the lower animals. Each upward step has been possible because of an important physical change—a better co-ordination of mind and body. It is true that in the course of development, sometimes one organ shoots ahead, sometimes another. The central nervous system has out-stripped all others.

Sir Arthur Keith said: "Civilisation is submitting the human body to a vast and critical experiment. It has laid bare some of the weak points in the human body but the conditions which have provoked them are not of Nature's ordaining but of man's choosing." In 1936, Hawkins speaking before the British Association for the Advancement of Science, said: "The high cerebral specialization that makes possible all these developments and the extraordinary rate at which success has been attained, point to the conclusion that this is a species destined to a spectacular fall more complete and rapid than the world has ever seen."

Let us take the physiologist's account of blood in human body and see that happens to the mind when the physical and chemical balance of the blood is disturbed:

(i) Overheat the blood and you rave. And yet men have to work nearly at the raving point in coal mines and boiler rooms, at the mouth of blazing furnaces to produce the things which society demands for its artificial environment.

(ii) Chill the blood: Bancroft, the famous physiologist, lay naked in an icy room. He described his sensation afterwards. "After a time" he later described "mind gave up the struggle". He was content to lie still and die. He would have died had not his vigilant assistant saved him. His mind ceased to watch over him.

(iii) Take away oxygen from blood. The mind loses its reasoning ability. The breathlessness at high altitudes is due to the nerves supplying the respiratory muscles failing to do their duty because of the want of oxygen.

(iv) Decrease calcium in the blood by half—Convulsion, coma and then death follows. Double the calcium: the blood thickens so that it can hardly flow. Heaviness, indifference, unconsciousness mark the stages of mind's dethronement; death is the end.

(v) Reduce the amount of sugar in the blood. There is a feeling of 'goneness', a blotting out of the mind, then death. Increase the sugar a little, fear seizes the mind: Illusions and Diplopia (double vision) ensue, speech becomes thick.

(vi) Blood is alkaline: acidify it slightly—Coma follows—mind becomes blank. Alkalinise the blood, convulsion ensues.

(vii) Take water from blood: we collapse. Add water: we suffer from headache, nausea and dizziness.

Therefore, change anything in the composition of blood and the mind gives way.

Civilisation changes the environments and thereby the physical and chemical conditions of the blood. Any changes in the environments—such changes as modern civilisation dictates—may be too much for body and hence for the mind. We want to anihilate distance and time with rockets and radio: we want to convert night into day with lamps that are miniature suns: we want to clothe ourselves in fabrics woven from fibres that nature did not provide. All these are incompatible with the survival of man as a species. In us a mind that yearns is at work, but the reward of successful yearning would be extinction. And yet human mind must go on experimenting in developing a quality of mind which curbs the tiger and the ape in him even at the risk of extinction.

Every man has his own worries: some have persecution complexes, suicidal mania, obsessions, indecisiveness, nervous tensions. They become problems to their families, nuisances to themselves, they become ineffective and unemployable in Society. What has happened to them? In appearance and structure they are indistinguishable from a solid citizen, observe all social conventions, even live an irreproachable life. And yet the affected persons cannot think logically. Why? In order to explain these phenomena, different parts of brains of animals were either removed or stimulated with electric current. It was discovered that there are centres in the brain which control movements, seeing, hearing, swallowing, winking, breathing, sweating and other activities. Effects of injuries to the human brain were also closely studied.

In 1935, a Portuguese Surgeon, Egas Moniz, first suggested that it was possible through Psychosurgery, to operate the brain, to stop worries, phobias and delusions. He had noted how stereotyped were the symptoms of the mentally disturbed patients. There were the same curses and lamentations, the same fury, the same wild looks, the same fits of weeping, the same lack of self-restraint under similar situations, even the same words and phrases were used to express their delusions and fears. It was clear to him that such a fixed pattern of conduct presupposed equally fixed pattern of brain cells that control passions, desires and fears. If the brain cell patterns could be changed, he thought the pattern of conduct could also be changed. How is the brain cell pattern fixed? By repetitive use. Any idea may become an obsession if it is entertained long enough. But we usually shake them off. Suppose, however, the mind is fatigued, the emotions are given no outward expression but are turned inward, and fear takes possession of the mind—the fear of losing a job, the fear of contracting an incurable disease, the fear of being the victim of a plot engineered by individuals. These fears are not so easily shed by a fatigued mind. Nerve messages flashing over the same pathways again and again involving the same group of cells become fixed as 'brain cell' patterns. To effect a cure, new pathways must be formed, new cells must learn how to form new groupings of cell patterns. Egas Moniz proved that fixed ideas could be dissipated by breaking up the link of the groupings of nerve cells through fixed pathways.

Scientists came to learn that the brain of a human being is not one piece, say, like the heart. The brain of an animal has through successive upgrading become the human brain. Nature modified the brain of this animal, enlarged the brain of that, contracted the brain of the third, developed a sense of hearing here and a sense of sight there. Nothing was thrown away. The record of the evolution of brain from the worm through the first toad, bird, dog, horse, ape is packed in the human skull. The work of Egas Moniz in Portugal and of Freeman and Watts in U.S.A. further showed that there is a complete association and interaction between two major parts of the brain in the human being. One is the Thalamus and the other is the Cerebrum which completely overlies the Thalamus. The Thalamus is one old component of the animal brain. Every animal from worm upwards has it. It is the seat of raw emotions, desires, passions, hatred, fear, combativeness, love, apetite. This Thalamus is incapable of thinking or imagining. Yet no nervous impulse set up by what we see, hear, feel, touch, taste or smell in the outer world could reach or leave the Cortex of the Brain without passing through Thalamus. Though Thalamus cannot think it can colour thinking.

If we had only Thalamus, we would fly into rage at the slightest irritation, burn up with hate, curl up with fear, woo with ferocity. Why is a bird always happy flying, twittering, fighting, courting, feeding, preening? Because its brain is largely Thalamus and this Thalamus is subject to little control. It is the enormous roof brain, the Cerebrum and its Cortex which makes Man what he is—the inventor, the philosopher, the moralist, the scientist, the planner. Yet with a Roof Brain alone human existence would probably be impossible. We would be unemotional. We would think without feeling. Never a tear would be shed over the death of a dear friend, never would we sigh in love, never a word of hate would escape us.

Man must balance emotion and reason. The preservation of this balance is a matter of nicely adjusting Thalamic feeling with Cerebral logic. One wants to drink because of the urge of the Thalamic cells, but the Prefrontal Lobes warn that this would be harmful. The desire to kill on an impulse is Thalamic, the fear of the law is Cerebral. When we yearn, fight, love and strive earnestly to satisfy the emotional needs, the Thalamus is on the ascendency ; only the prompt assertion of authority by the Prefrontal Lobes restores the poise and keeps us out of jail. Our brains are the battleground on which the old Thalamus and the new Prefontal Lobe strive for mastery. Cable of nerves, association fibres connect the Prefrontal Lobe with Thalamus. Impulses flow back and forth over the cables. In mental disorders, Thalamus overpowers the Prefrontal Lobes and anger, fear, worry, hate, triumph completely over common sense. The brain and nervous system are marvellously adjustable.

I have tried to place before you a short account of some of the research works undertaken by the scientists in the field of Chemotherapy. As a person interested in administration, I have to appeal to the scientists to contribute their share towards the development of the human society, where man may live in peace and in harmony with nature and with other human beings.

Our country is rich in natural resources and minerals as well as in human resources. But we have had yet no detailed statistics or data as to the way in which we can develop these resources for the benefit of the country and her people. It is admitted that we need heavy industries, we need machine industries and we need consumer goods industries. For all these we need trained technicians. The Planning Commission has estimated that in the Second Five Year Plan we will need thousands of Graduates and Diploma-holders in Civil Engineering, Mechanical Engineering, Electrical Engineering and Chemical Engineering. These men should not only possess the requisite technical knowledge, but should also be capable of utilising the resources that we possess. They should be able to put into use our indigenous raw materials for the great task that lies before us. In Japan I noticed that not only have they adopted the machines imported from abroad for their use, but they have simplified the technical processes in such a way that elaborate training in the use of such machinery is not necessary. While they have utilised highly technical personnel for some industries, in most other industries the ordinary mechanical instruments and gadgets have been discarded and replaced by methods which require manual skill so as to take advantage of their abundant manpower.

There are other directions in which the researches of the scientists may be very fruitful. Apart from securing increased food production or increased quantity of cash crops which would develop our nutrition, and improve our economy, it is important that we should train the agriculturists in improved agricultural techniques. The nature of the soil in an area, the manner in which it is affected by various types of manures and fertilisers, the methods of preserving seeds in a proper manner, are problems in which research would now be invaluable. As a result of research, traditional methods may have to be discarded and new methods adopted. At the same time there may be something to be learnt from indigenous and traditional practices. It has been my conviction and experience that if there be a disease prevalent in a particular area, the remedy has also been provided by nature in that area, if we have the patience to take the trouble to find it out. On one occasion I went to see a Blackwater Fever case in a part of Assam, where this disease is endemic and scores of people died of it. The treatment of such cases was then a despair to all physicians. On reaching the place I found that the local people used the leaves of a tree which grows locally for curing this type of fever. I got some of these leaves for experimental purposes. The scientists have succeeded in obtaining injectables from the extracts of the leaves and for the last 20 years I have not lost a single case of a Blackwater Fever by using this drug. I could give many instances of this character. Every problem has a solution to be found very near itself.

One sees in life many complex paradoxes. As man goes forward new problems arise. As work goes on new patterns of life emerge. This adventure of life continues. There is no finality about anything. Our ideal today may be a hundred years away from now ; the ideal then will again be a hundred years hence. As we proceed, the target appears to recede and bigger and better targets are formed. The clouds of time may have hidden for us innumerable problems, trials and dangers, yet time may also reveal solutions of unknown difficulties or delightful surprises, which man with his knowledge of science should be prepared to turn to his advantage with faith, hope and goodwill.

SECTION OF MATHEMATICS

PRESIDENT : K. CHANDRASEKHARAN, M.A., M.Sc., Ph.D., F.N.I.

Presidential Address

FUNCTIONAL EQUATIONS AND DIRICHLET SERIES

One of the most fascinating subjects of study at the cross-roads of function theory and number theory is the theory of zeta-functions originating from the work of Riemann. That a famous unsolved problem lies in this field is but a small token of its richness and depth. It may therefore be not altogether improper if I here discuss some of the questions that surround the fundamental properties of the zeta-function of Riemann.

1. FUNDAMENTAL FACTS ABOUT RIEMANN'S ZETA-FUNCTION.

If $s = \sigma + i\tau$ denotes a complex variable, then the series $\sum\limits_{n=1}^{\infty} n^{-s}$—(here we understand x^s, for $x > 0$, to mean $\exp (s \log x)$, where $\log x$ has its real determination)—converges for $\sigma > 1$ (and diverges for $\sigma \leqslant 1$), and represents a regular function, in the half-plane $\sigma > 1$, which, following Riemann, we denote by $\zeta(s)$. It can be shown that $\zeta(s)$ can be continued across the line $\sigma = 1$, and that it is a meromorphic function having a simple pole, with residue 1, at the point $s = 1$. The function is closely connected with prime numbers in as much as it has the 'Euler product'

$$\zeta(s) = \prod_p (1-p^{-s})^{-1}, \quad \sigma > 1, \qquad \ldots \quad (1)$$

where p runs through all the primes. As an immediate consequence one sees that

$$\zeta(s) \neq 0, \qquad \text{for } \sigma > 1. \qquad \ldots \quad (2)$$

One of the fundamental properties of Riemann's zeta-function is that it satisfies the 'functional equation'

$$\pi^{-\frac{1}{2}s}\Gamma(\tfrac{1}{2}s)\ \zeta(s) = \pi^{-\frac{1}{2}(1-s)}\ \Gamma\{\tfrac{1}{2}(1-s)\}\ \zeta(1-s). \qquad \ldots \quad 3)$$

In view of (3) it is sometimes convenient to deal with the properties of an associated function $\xi(s)$ which is defined by

$$\xi(s) = \tfrac{1}{2}s(s-1)\ \pi^{-\frac{1}{2}s}\ \Gamma(\tfrac{1}{2}s)\ \zeta(s). \qquad \ldots \quad (4)$$

Equation (3) can then be written as

$$\xi(s) = \xi(1-s). \qquad \ldots \quad (5)$$

From the known properties of the gamma-function, and from the definition of $\zeta(s)$, we see that $\xi(s)$ is regular for $\sigma > 0$, and by (5), it follows that it is regular for $\sigma < 1$; hence $\xi(s)$ is an entire function. Obviously $\xi(s)$ is real for real s, and therefore it takes conjugate values at conjugate points, so that $\xi(\frac{1}{2}+i\tau)$ and $\xi(\frac{1}{2}-i\tau)$ are conjugate; but they are equal by (5), hence they are real. Thus $\xi(s)$ is real on the line $\sigma = \frac{1}{2}$. Actually $\xi(1) = \frac{1}{2}$, and by (5), $\xi(0) = \frac{1}{2}$. One can show that *the zeros of* $\xi(s)$, *if any, lie in the strip* $0 \leqslant \sigma \leqslant 1$, *and are symmetrically situated about the line* $\sigma = \frac{1}{2}$. For, if we write

$$\xi(s) = h(s)\ \zeta(s), \qquad \ldots \quad (6)$$

where

$$h(s) = (s-1)\ \pi^{-\frac{1}{2}s}\ \Gamma(1+\tfrac{1}{2}s), \qquad \ldots \quad (7)$$

then, since we know that $\zeta(s) \neq 0$ for $\sigma > 1$, by (2), and that $h(s) \neq 0$ for $\sigma > 1$, it follows that $\xi(s) \neq 0$ for $\sigma > 1$, and, because of (5), $\xi(s) \neq 0$ for $\sigma < 0$. Since $\{\xi(\sigma \pm i\tau)\}$ are conjugates, the zeros of $\xi(s)$, if any, are symmetrical about the real axis; and about the point $s = \frac{1}{2}$, by (5); they are, therefore, symmetrical about the line $\sigma = \frac{1}{2}$. That $\xi(s)$ actually has zeros can be shown by an appeal to the theory of entire functions.

Because of (6), the zeros of $\zeta(s)$ differ from those of $\xi(s)$ only in so far as $h(s)$ has zeros or poles. Now the only zero of $h(s)$ is at the point $s = 1$, and this is not a zero of $\xi(s)$, since we have seen that $\xi(1) = \frac{1}{2}$, nor of $\zeta(s)$ since it is a pole of the latter. On the other hand, $h(s)$ has simple poles, arising from the gamma-function, at the points $s = -2, -4, -6, \ldots$ Since $\xi(s)$ is regular, and non-zero at these points, as we have seen, they must be simple zeros of $\zeta(s)$. These are called the *trivial* zeros of $\zeta(s)$, and all the non-trivial zeros of $\zeta(s)$ (which are the zeros of $\xi(s)$) lie in the strip $0 \leqslant \sigma \leqslant 1$. However, it is easy to see that $\zeta(s)$ has no zeros on the segment: $\tau = 0$, $0 < \sigma < 1$, for we have, for $\sigma > 0$,

$$(1-2^{1-s})\ \zeta(s) = (1-2^{-s})+(3^{-s}-4^{-s})+\ldots,$$

from which it follows that, if $0 < \sigma < 1$, we have

$$(1-2^{1-\sigma})\ \zeta(\sigma) > 0, \text{ or } \zeta(\sigma) < 0.$$

That $\zeta(s)$ has no zeros on the line $\sigma = 1$ is a much deeper property, which is equivalent to the prime number theorem, namely

$$\pi(x) \sim \frac{x}{\log x}, \text{ as } x \to \infty,$$

where $\pi(x)$ denotes the number of primes less than x. Thus *the non-trivial zeros of* $\zeta(s)$ *are all situated in the strip* $0 < \sigma < 1$, *which is called the critical strip, symmetrically about the line* $\sigma = \frac{1}{2}$, *which is called the critical line.* It can be shown that $\zeta(s)$ *does have an infinity of non-trivial zeros*, either by an appeal to the theory of entire functions or by a direct estimate.

If $N(T)$ denotes the number of zeros of $\zeta(s)$ in $0 < \sigma \leqslant 1$, $0 < \tau \leqslant T$, then the estimate of Riemann-Mangoldt gives

$$N(T) = \frac{T}{2\pi} \log \frac{T}{2\pi} - \frac{T}{2\pi} + 0\,(\log T), \qquad \dots \quad (8)$$

as $T \to \infty$, from which it follows that, if $h > 0$, then

$$N(T+h) - N(T) = 0(\log T), \text{ as } T \to \infty. \qquad \dots \quad (9)$$

It was conjectured by Riemann, and still unproved, that all the zeros in the critical strip lie on the critical line $\sigma = \frac{1}{2}$. Hardy showed that an infinity of the zeros do lie on the critical line. And in an attempt to prove Riemann's conjecture, Hardy and Littlewood showed that if $N_0(T)$ denotes the number of complex zeros of $\zeta(s)$ with real part $\frac{1}{2}$ and imaginary part between 0 and T, then

$$N_0(T) > cT, \qquad \dots \quad (10)$$

where c is a constant, in comparison with the estimate (8), namely $N(T) \sim \frac{1}{2\pi} T \log T$. (Riemann's conjecture is equivalent to the assertion that $N(T) = N_0(T)$). The result of Hardy and Littlewood was carried much farther by A. Selberg who proved (the best result so far) that

$$N_0(T) > c\,T \log T, \qquad \dots \quad (11)$$

which shows that a finite proportion of all the zeros of $\zeta(s)$ in the critical strip do lie on the critical line. It is a problem for the truly ambitious mathematician to go farther than (11)!

2. THE FUNCTIONAL EQUATION AND HECKE'S THEORY.

The functional equation (3), and the Euler product (1), are extremely important properties of $\zeta(s)$. The existence of the Euler product for $\zeta(s)$ is, in a sense, the basic connexion between $\zeta(s)$ and the theory of numbers. It was proved by Hamburger, on the other hand, that subject to certain conditions of regularity, $\zeta(s)$ is uniquely defined (up to a constant factor) by the functional equation.

To be precise: If $G(s)$ is an entire function of finite order, $P(s)$ a polynomial, and $f(s) = G(s)/P(s)$, and $f(s) = \sum\limits_1^\infty a_n n^{-s}$, the series converging absolutely for $Re\ s > 1$, and $g(1-s) = \sum\limits_1^\infty b_n n^{s-1}$, the series converging absolutely for $Re\ s < -\beta < 0$, then the equation

$$\pi^{-\frac{1}{2}s}\ \Gamma(\tfrac{1}{2}s)f(s) = \pi^{-\frac{1}{2}(1-s)}\ \Gamma\{\tfrac{1}{2}(1-s)\}g(1-s)$$

implies that $f(s) = g(s) = a_1\,\zeta(s)$.

This theorem of Hamburger can be viewed as the starting point for Hecke's beautiful theory of modular forms and Dirichlet series. The functional equation of $\zeta(s)$ is known to be a consequence of the transformation formula for the theta-function:

$$\vartheta(t) = \sum_{n=-\infty}^{\infty} e^{i\pi n^2 t}, \quad Im\ t > 0,$$

$$\vartheta\left(-\frac{1}{t}\right) = (-it)^{\frac{1}{2}}\ \vartheta(t). \qquad \ldots \quad (12)$$

Generalizing this idea, Hecke set up a correspondence between Dirichlet series of the type $\sum\limits_1^\infty a_n\, n^{-s}$ with a given *signature*, and modular forms. A Dirichlet series $\sum a_n n^{-s}$, which converges somewhere to the sum function $\phi(s)$, is said to have the signature $(\lambda, \kappa, \gamma)$, where $\lambda > 0$, $\kappa > 0$, and γ is an arbitrary constant, if $(s-\kappa)\phi(s)$ is an entire function of finite order, and $R(s) = \gamma R(\kappa - s)$, where

$$R(s) = \left(\frac{2\pi}{\lambda}\right)^{-s}\ \Gamma(s)\ \phi(s).$$

(It follows from the assumptions that $\gamma = \pm 1$; $\zeta(s)$ is obviously the special case which arises when $\lambda = 2$, $\kappa = \frac{1}{2}$, $\gamma = 1$.) To every Dirichlet series with signature $(\lambda, \kappa, \gamma)$, Hecke showed that there corresponds a unique 'modular form' $f(t)$ with the properties: (i) $f(t+\lambda) = f(t)$; (ii) $f(t)$ is regular in $e^{2\pi i t/\lambda}$ in the upper half plane of t; (iii) $f\left(-\frac{1}{t}\right) = (-it)^{\kappa}\ \gamma\, f(t)$; (iv) $f(x+iy) = 0(y^{c})$, as $y \rightarrow +0$ uniformly in x, c being a constant. Conversely to every $f(t)$ satisfying these four conditions, there corresponds a Dirichlet series with signature $(\lambda, \kappa, \gamma)$. The quotient of two such functions $f(t)$ with the same signature $(\lambda, \kappa, \gamma)$ is an analytic function of t, invariant under the group $G(\lambda)$, generated by the substitutions $t \rightarrow t+\lambda$ and $t \rightarrow -\frac{1}{t}$, or an automorphic function (modular function when $\lambda = 1$). Using the correspondence thus set up, together with the properties of modular and automorphic forms, Hecke showed that if $\lambda > 2$, then for every positive κ there exists an infinity of linearly independent Dirichlet series with the signature $(\lambda, \kappa, \gamma)$, and that if $\lambda \leqslant 2$ the number of such linearly independent Dirichlet series is finite. This places Hamburger's theorem in an altogether more general setting. What is more, Hecke showed, by using new algebraic properties of modular forms, that some of the corresponding Dirichlet series, which are of importance in arithmetic, have Euler products, a fact not known previously.

3. General Dirichlet Series and Functional Equations.

Instead of asking for the number of linearly independent Dirichlet series of the type $\Sigma\ a_n n^{-s}$ with a given signature, by way of generalizing Hamburger's theorem, one can ask for the number of linearly independent 'solutions' of a "generalized functional equation" in terms of "general Dirichlet series" of the type $\Sigma\ a_n \lambda_n^{-s}$. The problem can be posed precisely as follows : Given the sequences $0 < \lambda_1 < \lambda_2 < \ldots < \lambda_n < \ldots \rightarrow \infty$, and $0 < \mu_1 < \mu_2 < \ldots < \mu_n < \ldots \rightarrow \infty$, and a number $\delta > 0$, we call the triplet $(\delta, \lambda_n, \mu_n)$ a *label*, and we speak of a solution of the functional equation

$$\pi^{-\frac{1}{2}s}\, \Gamma(\tfrac{1}{2}s)\, \phi(s) = \pi^{-\frac{1}{2}(\delta-s)}\ \Gamma\{\tfrac{1}{2}(\delta-s)\}\psi(\delta-s) \qquad \ldots \quad (13)$$

if there exists

(i) a Dirichlet series $\phi(s) = \sum\limits_{1}^{\infty} a_n \lambda_n^{-s}$ with complex a_n, not all zero, which converges absolutely for $\sigma > \alpha$, for some finite α, and

(ii) a Dirichlet series $\psi(s) = \sum\limits_{1}^{\infty} b_n \mu_n^{-s}$, with complex b_n not all zero, which converges absolutely for $\sigma > \beta$ for some finite $\beta > 0$, and

(iii) a bounded closed set S in the s-plane, such that if R is its exterior, there exists in R a holomorphic function $\chi(s)$ which coincides in a right half-plane with

$$\chi_1(s) \doteq \pi^{-\frac{1}{2}s}\ \Gamma(\tfrac{1}{2}s)\ \phi(s),$$

and in a left half-plane with

$$\chi_2(s) = \pi^{-\frac{1}{2}(\delta-s)}\ \Gamma\{\tfrac{1}{2}(\delta-s)\}\psi(\delta-s),$$

and for which

$$\lim_{|\tau|\to\infty} \chi(\sigma+i\tau) = 0$$

uniformly in every bounded interval $\sigma_1 \leqslant \sigma \leqslant \sigma_2$, $-\infty < \sigma_1 < \sigma_2 < +\infty$. Such a pair of functions $\{\phi(s), \psi(s)\}$ is called a *solution* of the functional equation (13) pertaining to the given label $(\delta, \lambda_n, \mu_n)$. It is easy to see that if $\{\phi_1(s), \psi_1(s)\}$ and $\{\phi_2(s), \psi_2(s)\}$ are solutions pertaining to the label $(\delta, \lambda_n, \mu_n)$, then

$$\{c_1\phi_1(s)+c_2\phi_2(s),\ c_1\psi_1(s)+c_2\psi_2(s)\},$$

for complex c's, is also a solution, and we can speak of *linearly independent* solutions. The problem is to determine the number of linearly independent solutions of (13).

If $\lambda_n = n$, $\mu_n = n$, and $a_n = 1$, $b_n = 1$, and $\delta = 1$, then $\phi(s) = \psi(s) = \zeta(s)$ and equation (13) reduces to (3). It can be shown, by suitably generalizing Siegel's proof of Hamburger's theorem, that equation (13) implies the following relation:

$$\frac{\Gamma\{\frac{1}{2}(\delta+1)\}}{\pi^{\frac{1}{2}(\delta+1)}} \sum_{1}^{\infty} a_n \frac{d^{2r}}{dt^{2r}}\left[\frac{t}{(t^2+\lambda_n^2)^{\frac{1}{2}(\delta+1)}}\right] - K_r(t)$$

$$= (2\pi)^{2r} \sum_{1}^{\infty} b_n\mu_n^{2r} \exp\,(-2\pi\,.\,\mu_n t), \qquad \dots \quad (14)$$

where r is a sufficiently large integer, $K_r(t)$ is holomorphic on the surface on which $\log t$ is defined, and $K_r(t) = 0\ (t^{-2\epsilon})$, $\epsilon > 0$, as $t \to \infty$ in any angle $|\arg t| \leqslant \theta_0$.

From (14) it follows immediately that the functional equation precludes the possibility of the λ_n's or μ_n's being finite in number. For if the μ_n's, for example, were finite in number, the right side of (14) would be entire, while the left side would not. In other words, in a general label it cannot happen that all but a finite number of the b_n's (or a_n's) are zero.

The right side of (14) is a Dirichlet Series with exponents μ_n, which converges absolutely to the right of the imaginary axis, with $(\pm i\lambda_n)$ as the singularities of its sum-function on the axis of convergence. Classical theorems on the location of such singularities enable us to relate the distribution of λ_n and μ_n with the existence of solutions of the functional equation. For instance, we have the following theorem of Polya :

If $f(s) = \sum_1^\infty a_n \exp(-2\pi\mu_n s)$ *converges for* $\sigma > 0$, *but not for* $\sigma < 0$, *and*

$$\lim_{n\to\infty} \inf (\mu_{n+1} - \mu_n) > 0, \qquad \ldots \quad (15)$$

and

$$\lim_{n\to\infty} \frac{n}{\mu_n} = D < \infty,$$

then every interval of length greater than D on the imaginary axis contains a singularity of $f(s)$. Taken in conjunction with (14), this result shows first that if

$$\lim_{n\to\infty} \frac{n}{\mu_n} = 0, \quad \lim_{n\to\infty} \inf (\mu_{n+1} - \mu_n) > 0,$$

then there can be no solution of the functional equation, since every point of the imaginary axis would then be a singularity of the right side of (14), whereas we know that only the points $(\pm i\lambda_n)$ could be such.

Secondly, it shows that if the conditions on μ_n, imposed in (15), hold, then the maximum number of linearly independent solutions of the functional equation is equal to the minimum number of λ_n's that lie in any interval of length exceeding D. We reason as follows: The series on the right of (14) converges absolutely for $\sigma > 0$, and since not all the b_n's are zero, the right side of (14) must have at least one singularity on the line $\sigma = 0$, and the only possible singularities on the line are $\pm i\lambda_n$, $n = 0, 1, 2, \ldots$ (if we designate $\lambda_0 = 0$). Next, if there exists an interval of length exceeding D on the imaginary axis which is free of all λ_n's, then by Polya's theorem, all the b_n must vanish. If, on the other hand, there exists an interval, say l_r, of length exceeding D, which contains exactly one λ_n, say λ_r, then there can be at most one solution (all the others can only be constant multiples of it). Let (a_n, b_n) correspond to one solution, and, if possible, (a_n', b_n') to a second solution. Then by choosing a suitable constant c such that $c\,a_r' = a_r$, we see that the series $\sum_1^\infty (b_n - c\,b_n') \exp(-2\pi\mu_n t)$ has no singularity in the interval l_r, so that by Pólya's theorem $b_n = c\,b_n'$ for all n, and $a_n = c\,a_n'$. By repeating the argument, one can see that if there exists an interval of length exceeding D which contains exactly p of the λ_n's then there can be at most p linearly independent solutions.

If $\lambda_n = n$, $\mu_n = n$, and $a_n = 1$, $b_n = 1$, then $D = 1$, and there can be at most one solution; it was proved by Riemann that there exists at least one solution, namely $\zeta(s)$. So it is the only solution, which proves Hamburger's theorem.

It is obvious that by applying this general procedure one can derive a number of results. Thus by using Mandelbrojt's generalization of Polya's theorem it can be shown under the more general assumptions

$$\limsup\,(n/\mu_n) = D^{\mu} < \infty, \qquad \liminf\,(\mu_{n+1}-\mu_n) > 0, \qquad \ldots \quad (16)$$

that the maximum number of linearly independent solutions of the functional equation is equal to the minimum number of λ_n's that lie in any interval of length exceeding D^{μ}.

The number D used in (15) is called the *density* of μ_n; the number D^{μ} in (16) is called the *upper density* of μ_n; similarly one can define the *lower density* $D_{\mu} = \liminf\,(n/\mu_n)$.

The appeal to density theorems such as Polya's can be avoided if we use a stronger concept of density called the '*modular density*' d_{μ} of μ_n. It can be shown that if d_{μ} is finite, then the maximum number of linearly independent solutions of the functional equation (13) is equal to the mininum number of λ_n's that lie in an interval of length exceeding d_{μ}. Further, the functional equation always implies that $d_{\lambda}.d_{\mu} \geqslant 1$ (with the understanding that if one of the d's is zero, the other is ∞), and if there exists an integer k such that $d_{\lambda} . d_{\mu} < k+1$, then the functional equation has atmost k linearly independent solutions. If $d_{\lambda} = d_{\mu} = 1$, and the coefficients a_n are, for instance, bounded, then the functional equation implies that $\lambda_{n+1}-\lambda_n = 1$ for every n, so that there can be at most one solution. Since it can easily be shown that in case $\lambda_n = n$, $\mu_n = n$, we have $d_{\lambda} = d_{\mu} = 1$, the above result yields a sharpened form of Hamburger's theorem as a special case. [The proof of the result requires use of the theory of almost periodic functions.] If, on the other hand, we assume that $d_{\lambda} = d_{\mu} = 1$, and $\mu_{n+1}-\mu_n = 1$ for $n \geqslant n_0$, then it can be shown that $\lambda_n = n$ or $n-\frac{1}{2}$, $\mu_n = n$ or $n-\frac{1}{2}$; and $\delta = 1$ or 3; and the only solutions that can occur are those known, namely

$$\zeta(s),\ (2^s-1)\ \zeta(s),\quad (2^{1-s}-1)\,\zeta(s),\quad \text{and}\quad 2^{s-1}\,L\,(s-1).$$

Finally, if in a solution we have $\mu_{n+1}-\mu_n = 1$ for $n \geqslant n_0$, and in the sequence b_n there are at most finitely many different terms, then $\delta = 1$, $\mu_n = n$, $a_n = a_{n+k}$ for a certain positive integer k, $\lambda_n = n/k$, and

$$b_n = \sum_{q=0}^{k-1} a_n \cos\,(2\pi qn)/k,$$

and Hurwitz's zeta-function arises as a solution.

This analysis leads to a variety of results and several new problems. In the first place, one can ask for criteria for the *existence* of solutions, and not merely for their uniqueness; in the second place, one can ask whether the concept of 'modular density' that has been used is connected with that of *maximal* or *minimal density* in the sense of Polya; there is reason to believe that it is; in the third place, one can generalize the functional equation in the manner of Hecke by introducing multiple gamma factors; in the fourth place, one can ask whether further arithmetical assumptions on λ_n and μ_n would reduce the number of solutions, and so on. This brief exposition will have served its purpose if the attention of those interested in the subject is drawn to some of these concrete problems, which are by no means very difficult.

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SECTION OF STATISTICS

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Presidential Address

STATISTICAL METHODS IN PSYCHOMETRIC RESEARCH

General Introduction

Statistical Science is developing at a very rapid stride for the last quarter of a century. Recent developments of statistical concepts and theory provide a very useful tool for solving certain problems in fundamental sciences while its applications extend to the whole field of applied and social sciences. Thus it is a rather difficult task to choose a suitable topic for the address, which will be of interest to all the statisticians assembled here. So with a good deal of hesitation I have chosen "Statistical Methods in Psychometric Research" as the topic of my address.

Indian statisticians have made useful contributions in theoretical statistics and also in some branches of applied statistics. But somehow this particular branch of applied Statistics has not attracted much attention of the Indian statisticians. Under the able guidance of Prof. Cyril Burt, Psychometricians are working in quantitative Psychology for the last fifty years in U.K., but statistical techniques have been used on a large scale in Psychometry only after the establishment of the Psychometric Society in U.S.A. in 1935. In Psychological experiments we mainly deal with three types of variables, (i) Stimulus variable, (ii) Response variable and (iii) Organismic variable. By stimulus I mean something which creates excitement when it is applied to individuals. The effect of such excitement is known as 'response'. Thus 'Stimulus' may be looked upon as the cause and 'Response' as the effect of any process. To use statistical methods for analysing such processes we have to quantify 'Stimulus' and 'Response' by following certain fixed principles. After quantification they are called 'Stimulus Variable' and 'Response Variable', or, in other words, they are known as psychometrical measurements. Organismic variables on the other hand arise from the physical, (qualitative or quantitative), psychologial or physiological measurements of individuals. The primary concern of the psychologists and other scientists who are interested in the behaviour of individuals is to study the relationship between the variables enumerated above. These relationships are carefully analysed to put forward a rational basis for explaining the behaviour pattern of individuals under different situations.

PART I. GENERAL PRINCIPLES

If we trace the early history of mental measurements we find that the development of Psychometry proceeded on two independent lines. On one hand there was the psychophysical theory which owed its origin from experimental physiology and the other was the mental test theory which grew up from the ideas of evolutionary biology. But both methods were based to a great extent on mathematics of probability. Fechner laid the foundation of classical Psychophysical theory. The essential feature of Psychophysical theory is to establish a relationship between body and mind i.e. between 'Stimulus' and 'Response'. For this purpose we conceive of two continuous scales, one a physical scale on which stimulus is measured and the other a psychological scale on which response is measured. In Psychological scales we have to specify the two end points and the units of measurements. Let us take two scales side by side. For a particular value of the stimulus on the physical scale there will be corresponding values of response on the psychological scale. At the lower end of the scale for some values of the stimulus there will be no response but as we increase the magnitude of the stimulus we reach at a transition zone where we get reactions at times; as we increase the magnitude of the Stimulus further we get response always. We experience a similar thing at the other extremity of the scale. The two ends on a Physical scale are called stimulus limen S_0 and terminal stimulus S_t. They are defined statistically as follows: S_0 and S_t are those values of a stimulus whose probability of arousing a reportable sensation is 0.50. Corresponding values for S_0 and S_t may be marked on the psychological scale. They are the end points of the scale. The difference limen DL is defined as a stimulus difference that is noticed 50 per cent of the time. Corresponding to any DL we have an increment in R which may be taken as the unit on the Psychological scale.

The general behaviour equation in psychophysics may be stated as

$$R = \phi(\alpha, \beta, \gamma, \delta \ldots n, \quad t \ldots x), \qquad \ldots \quad (1)$$

Where R is the response or the behaviour

$\alpha, \beta, \gamma, \delta \ldots$ = aspects of stimulus,
n = number of times the stimulus is applied,
t = interval, and
x = personal factor.

In experimental sciences when we want to study the effect of any particular factor on any thing, we keep constant all subsidiary factors besides that factor. Here also we simplify the behaviour equation as $R = \phi(\alpha)$ keeping all other factors as constants. This type of equation will give rise to two different types of response matrices, one an occasion matrix and another an individual matrix. In psychophysics we are interested about the occasion matrix, whereas in the mental test theory we deal mainly with individual matrix. Occasion matrix is necessary in psychophysics because organisms do not react similarly on each occasion, or, in other words, there is no one-to-one correspondence between the stimulus and the response. A particular value of the stimulus will give rise to a process which is called discriminal dispersion with a modal value. The modal discriminal response is known as the true value of the response.

It is a very striking fact that the discriminal dispersion for a particular stimulus is of normal form. It may so happen that for a higher value of stimulus, response may be less. This will be evident from the following diagram.

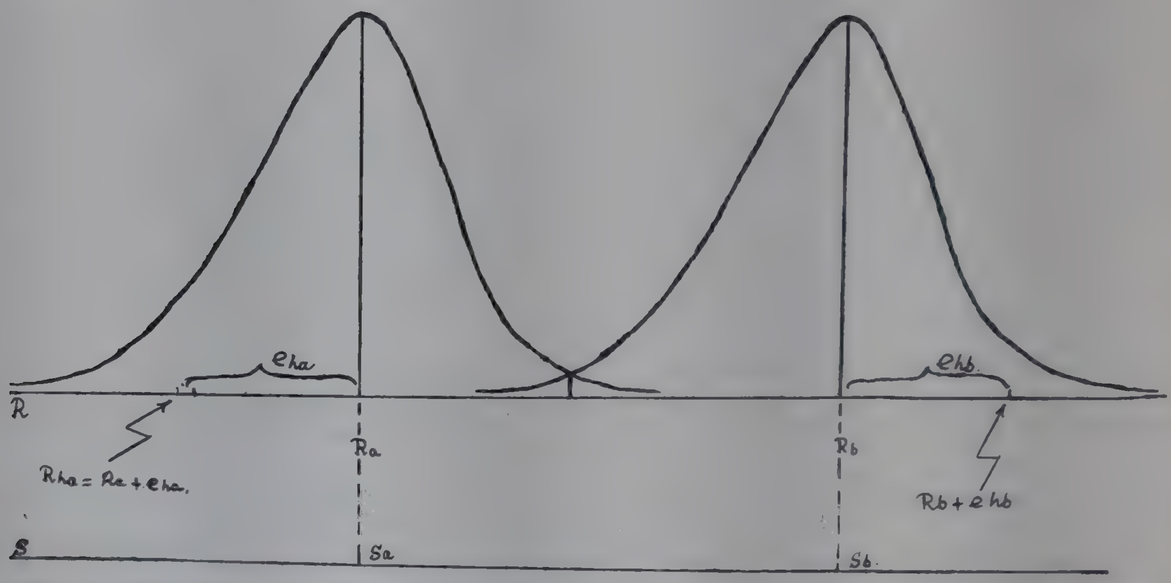

Fig. 1 Two discriminal dispersions on the R-scale corresponding to two stimuli

There is a common region between the two curves and in this region it is possible for a higher stimulus value to have a lower response. It is difficult sometimes to record the response values directly, and they have to be inferred from judgements. Really speaking we are using three scales, stimulus, response and judgement; thus in modern psychophysics we have added a third judgement continuum in addition to the existing two. It is assumed in psychophysics that there is a perfect correlation between the response and the judgement and that the regression between the two is linear. But this assumption is not always valid.

There are important psychophysical laws which are of vital importance. The first law is due to Fechner which connects stimulus and response by the following formula;

$$R = c \log S \qquad \ldots \quad (1.1)$$

The second law is called the 'Law of Comparative Judgement'. This is due to Thurstone. The law states

$$R_b - R_a = Z_{ba}\sqrt{\sigma_a^2+\sigma_b^2-2r_{ab}\sigma_a\sigma_b}, \qquad \ldots \quad (1.2)$$

Where Z_{ba} is the normal deviate, R_b, R_a are the response values for S_b and S_a; and σ_a, σ_b and r_{ab} are the respective standard deviations and correlation. The law of comparative judgment affords a very valuable method for scaling individuals.

In test theory we also deal with stimulus and response but their forms and modes of application are different. Here stimulus is in the form of a test and response is in the form of a score. In classical psychophysical theory we have tried to evaluate the individuals from their bodily traits but here we try to measure intelligence directly. In test theory the first important task is to design a test. A test should fulfil certain properties. According to different situations, test contents will be different, but as a whole it must be a reliable and a valid test. When a test has been properly designed, it is applied on a selected group of individuals. The numerical evaluation of their performances is known as score. This forms the primary basic material for psychometric analysis. The true score and the observed score of any individual is represented by a simple relation

$$X_i = T_i + E_i \qquad \ldots \quad (1.3)$$

where E_i is the random error component. For random error component it will not be unreasonable to assume (i) $M_E = 0$,

(ii) $r^{+}_{TE} = 0$ and (iii) $r_{E_1E_2} = 0$

When we consider a large number of individuals, our aim is to determine the true score of any individual but as it is not possible to ascertain it we have got to estimate it. The definition of true score may be given as

$$T_i = \lim_{k\to\infty} \sum_{g=1}^{k} \frac{X_{ig}}{k} \qquad \ldots \quad (1.4)$$

Where k is the number of parallel tests. In actual practice $k\to\infty$ does not carry much sense. Instead of observed score of any individual in any test it is better to have a stable score. By stable score we mean a score which is based on a number of tests (preferably three or four) which are parallel, and we take the stable score as an estimate of the true score. Psychometricians should begin to think in terms of stable scores and not in terms of observed scores. Scores are quantitative evaluation of one's performance; unless these are correctly estimated future analysis will not give us convincing conclusion. As a first step to this we have to design a number of parallel tests. In order that the tests should be parallel they must satisfy certain conditions.

The conditions are

$$\left.\begin{array}{ll} \text{(i)} & m_1 = m_2 = \dots = m_k \\ \text{(ii)} & \sigma_1 = \sigma_2 = \dots = \sigma_k \\ \text{(iii)} & \rho_{12} = \rho_{13} = \rho_{23} = \dots \end{array}\right\} \quad \dots \quad (1.5)$$

i.e. when parallel tests are applied on a sample of individuals,among the set of scores so obtained, we expect the differences of means,.standard deviations and intercorrelations to be statistically insignificant. To test this we have to evolve a composite statistical test. The test is due to S. S. Wilks. (1946).

Having constructed one main test and a few auxiliary tests which are all parallel we can estimate the true score of any individual which is known as a stable score. There are two most important properties which should be fulfilled by standardised tests. The test should be a reliable and a valid one. The coefficients of reliability and validity should be high. The reliability coefficient has been defined as the correlation coefficient between two parallel forms of a test. The first important formula on test reliability was given by Spearman-Brown. This formula gives us a relation between the reliability of the original test and the lengthened test.

$$R_{kk} = \frac{kr_{11}}{1+(k-1)r_{11}} \quad .. \quad (1.6)$$

Where R_{kk} is the reliability of the lengthened test and k is the number of items in the lengthened test divided by the number of items in the unit test.

But this formula is not sufficient to determine the reliability of any test. Kuder and Richardson first gave a formula for finding out the reliability coefficient; subsequently this has been discussed by Dressel, Hoyt, Bose and Chaudhury and others. The methods for finding out the test reliability are either by constructing an alternate set of parallel test or by splitting the test into two parts such that they are parallel. From the point of view of application there are some difficulties regarding the first as we have to construct a parallel test every time; as regards the second there will be $n!/2\left(\frac{n}{2}!\right)^2$ different ways of dividing the test of n items and hence there will be difficulty in getting a unique value. To obviate these difficulties

Kuder and Richardson (1937) suggested a formula under some simplifying assumptions. The formula is given below:

$$r_{tt} = \frac{n}{n-1} \frac{\sigma_t^2 - n\overline{pq}}{\sigma_t^2} \quad .. \quad (1.7)$$

where n is the number of test items, σ_t^2 is the test variance and $\overline{pq}$ is the average item variance.

Bose and Chaudhury (1956) removed to a great extent the second objection that was put forward by Kuder and Richardson. They gave a method by which a test can be split in a unique manner such that the two halves are parallel. The correlation between two halves when corrected by Spearman-Brown formula will give an estimate of test reliability.

The second important property that should be fulfilled by a properly standardised test is that the coefficient of validity should be high. Coefficient of validity has been defined as the correlation coefficient between the test and the external criterion. A problem that often arises is that whether parallel tests should have equal validities for predicting any criterion. By using the statistical test of compound symmetry proposed by Votaw (1948) we can test for the equal validities of a set of parallel tests. If we assume the scores of individuals in n forms of tests and the criterion have a normal $(n+1)$ variate distribution, the hypothesis of interchangeability means the equality of means, equality of variances and equality of covariances between forms and the criterion. A normal distribution for which this hypothesis is true is said to have compound symmetry.

PART II. SOME PROBLEMS OF PSYCHOMETRY.

We are mentioning below a few problems of psychometry where statistical methods have been used. They are (i) Scaling procedures (ii) Weighting and Differential prediction (iii) Decision problems (iv) Model Study. It is difficult to give a detailed account of these topics, and only the main points will be discussed.

(i) SCALING PROCEDURES

We have already referred to two important variables in psychometry, one a stimulus variable and the other a response variable. Either we have to scale the stimulus or we have to scale the individuals. On a number of occasions suppose an individual judges the nature of stimulus. From the proportion matrix we may have to rate the stimuli. This type of problem often arises in psychophysics. On the other hand we may apply a particular test battery on a group of individuals on a single occasion. From the records of scores we may have to rate the individuals. This type of problem arises in test theory. Rating of stimuli on a number of occasions is done by the 'Method of paired comparisons'.

Thurstone's law of comparative judgement (1927) states

$$R_j - R_k = z_{jk} \sqrt{\sigma_j^2 + \sigma_k^2 - 2r_{jk}\,\sigma_j\,\sigma_k} \qquad .. \quad (2.1)$$

where R_j and R_k are the response variables for the two stimuli j and k. Under the most simplifying assumptions that the discriminal dispersions are same and that there is no correlation between responses for any pair of stimuli and using σ_j as the unit of scale,

$$R_j - R_k = z_{jk} \sqrt{2} \qquad .. \quad (2.2)$$

where z_{jk} is the deviation from mean of a unit normal distribution. A proportion matrix can easily be converted into z-variables with the help of normal tables, and then using Thurstone's simplified law we can find out the scale separations between a pair of stimuli. From these scale separations, adding successively we get the numerical value for each stimulus. We can represent these values on a scale and hence we can find out their relative positions. This method is often used in psychophysics for scaling purposes. Method of Paired comparisons has been mostly applied in the field of sensory discrimination and in scaling attitudes and opinions. But with slight modification this method can be used also for scaling individuals in test theory. A problem often arises whether Thurstone's simplified assumptions are valid or not. Their internal consistency can be very easily tested by using a χ^2 test; Vide Mosteller (1951). Expected value of the proportions can be calculated from the scale values. He has given a method by which a single χ^2 test will test the entire matrix of proportions. The statistic is given below

$$\chi^2 = \frac{N}{821} \sum_{i<j} (\theta''_{ij} - \theta'_{ij})^2 \qquad ... \quad (2.3)$$

$$df = \frac{(n-1)(n-2)}{2}$$

here N is the number of judgments per pair of stimuli and n = number of stimuli,

$$\left.\begin{aligned} \theta'_{ij} &= arc \sin \sqrt{p'_{ij}} \\ \theta''_{ij} &= arc \sin \sqrt{p''_{ij}} \end{aligned}\right\} \qquad ... \quad (2.4)$$

p'_{ij} are the observed proportions and p''_{ij} are the proportions derived from S_i.

In test theory we rate a number of individuals from the scores in various tests. While scaling by the method of average, in most of the cases, we ignore the inter-test variation. Thus this method often leads us to absurd conclusions. To avoid this, idea of equivalent scores in tests has been conceived. This topic has been discussed by Mahalanobis and Chakravarti (1934), Greenall (1949), Bose and Chaudhury (1955). While Mahalanobis and Greenall developed the idea of equivalent scores in similar tests, Bose and Chaudhury gave a general method of constructing equivalent scores even when tests are not similar in nature. From the frequency distribution of scores of any test on a sample of individuals we can find out the nature of the parent population. If for the two tests, nature of the parent populations is the same, we call the two tests to be similar.

Let us take $f(x)$ and $\phi(y)$ as the probability density functions for the two variables x and y. The proportion of x scores less than x_i-and the proportion of y-scores less than y_i are given by the expressions,

$$\int_{-\infty}^{x_i} f(x)dx \text{ and } \int_{-\infty}^{y_i} \phi(y)dy \qquad \ldots \quad (2.5)$$

x_i and y_i are said to be equivalent if the two integrals are equal. If we have similar tests and if the distribution functions are normal we can find out an equivalence line as

$$y_0 = m_y + \frac{\sigma_y}{\sigma_x}(x - m_x) \qquad \ldots \quad (2.6)$$

This relation will give us a set of equivalent scores. In case of non-normal variations of one or both of the variables such a simple functional relationship can not be found out. We have to equate the respective percentile points for the two distributions, i.e.

$$\frac{p}{100} = \int_{-\infty}^{x_i} f(x)dx = \int_{-\infty}^{y_i} \phi(y)dy \qquad \ldots \quad (2.7)$$

From these percentile points we have to find out an equivalence curve. This curve will give us the set of equivalent scores.

Equivalent scores take into account the inter-test variations and with the new scores proper rating can be done. In scholastic tests equivalent scores can also be utilised for judging the standard of tests from year to year. This technique has been utilised for rating and also for ascertaining the standard of tests with very good result. It has been found that ranking becomes altogether different both in the University and competetive examinations if we use the equivalent scores instead of raw score.

(ii) WEIGHTING AND DIFFERENTIAL PREDICTION

In problems of weighting we are faced with two types of problems. To weight the test scores (i) when an external criterion is available, and (ii) when an external criterion is not available.

(A) *When an external criterion is available*

Let y be a dependent variable (which is considered as a criterion variable) and $x_1, x_2, \ldots, x_n$ are independent variables (scores in different tests). By criterion variable we mean a variable which measures ability directly in a particular field of activity. Each individual in a sample from a particular population is measured on each of the $(n+1)$ variables $y, x_1, x_2, \ldots x_n$: for the α-th individual, observations are $y_\alpha, x_{1\alpha}, x_{2\alpha}, \ldots x_{n\alpha}$. A criterion variable is to be approximated as closely as possible by a weighted sum of independent variables,

$$L = \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n \qquad \ldots \quad (2.8)$$

We have to determine β's so that L is the best linear function of the x's for estimating y's. In the sense of least squares we have to find β's such that $\sum\limits_{\alpha}(y_\alpha - L)^2$ is a minimum. It is well-known that the values of β's which minimise the sum of squares are the regression coefficients $b_{01\cdot 23\cdots n}$, $b_{02\cdot 13\cdots n}$ etc (where y has been regarded as x_0).

Regression coefficients can be obtained easily from correlation coefficients by using Aitkin's Method of pivotal condensation (Bose, 1946). For determining the weights, computing methods become prohibitive as we increase the number of tests. So it is worthwhile to consider whether for the purpose of prediction we can omit certain tests without losing some valuable information. Let us call T as the full test battery, T_l as the short test battery. To judge how much we have lost in predictive accuracy by using T_l instead of T, we have to calculate the two multiple correlation coefficients. The problem arises now how to choose T_l from T so that the difference between the two multiple correlations is non-significant. To do this selection we have to compute multiple correlations and multiple regression weights for all combinations of the tests. From these expressions we have to choose the appropriate tests.

(B) *When external criterion is not available*

There are certain cases where no external criterion is available but we have to determine the best set of weights. This can be done either by maximising the reliability between the two weighted composites or by maximising the correlation between the two weighted composites. For the first case we have to construct a set of parallel tests to the given battery of tests so that reliability coefficient for each test may be ascertained.

The general method of procedure is the same in two cases. We are considering the second case. This is due to Hotelling (1935).

The correlation between the two composites may be written down in matrix form as

$$Rx_lx_m = \frac{LCM'}{\sqrt{LRL'}\sqrt{MSM'}} \qquad \dots \quad (2.9)$$

where R is the matrix of inter correlation of tests for the first test battery.
S ,, ,, ,, ,, ,, ,, ,, second ,, ,,
C ,, ,, ,, ,, of the first battery with those of the second battery.
L ,, row vector of weights for the first battery.
M ,, ,, ,, ,, ,, second battery.

To determine the weights for the maximum value of Rx_lx_m we impose the further restrictions namely

$$LRL' = MSM' = 1$$

Let us define a new function

$$R = LCM' - \lambda/2(LRL'-1) - \gamma/2(MSM'-1) \qquad \dots \quad (2.10)$$

where λ and γ are Lagrangian multipliers.

Using the usual methods of calculus following relations may be obtained:

$$\left.\begin{array}{ll} \text{(i)} & \gamma = \lambda = Rx_lx_m \\ \text{(ii)} & L(CS^{-1}C' - \lambda^2 R) = 0 \\ \text{(iii)} & M(C'R^{-1}C - \lambda^2 S) = 0 \end{array}\right\} \qquad \dots \quad (2.11)$$

Relations (ii) and (iii) will give values of L and M other than zero when

$$\begin{array}{l} |CS^{-1}C' - \lambda^2 R| = 0 \\ |C'R^{-1}C - \lambda^2 S| = 0 \end{array} \qquad \dots \quad (2.12)$$

We have to determine the weights such that Rx_lx_m is maximum. This will correspond to the largest root of λ^2 in the above determinantal equation. We choose the largest root of λ^2, and substituting this value in the relations (ii) and (iii) weights can be found out corresponding to the maximum correlation coefficient.

Following exactly as before, for the first case, we shall have a single determinantal equation of the form

$$|A-\lambda R| = 0 \qquad \text{... (2.13)}$$

where A is the matrix of inter-correlation between the tests of two parallel batteries. We choose λ as the largest root and then from $W(A-\lambda R) = 0$, we can find out the set of weights. Thomson (1940) and Peel (1948) have considered this problem. Green Jr. (1950) has given a practical method for solving the equation $|A-\lambda R| = 0$ and also for determining the set of weights.

(iii) DECISION PROBLEMS

In psychometry we face different types of problems of classification. Suppose on the basis of multiple test scores we want to classify the individuals into two groups with a minimum of overlapping. We wish to know what function of the test-scores available will discriminate most accurately the two groups. Suppose further that from past experience we know the scores of N_1 individuals who belong to one population and the scores of N_2 individuals who belong to a second population. The problem arises how to classify a new individual on the basis of his test scores in one of the known groups. The solution of the first type of problem has been given by Fisher (1936) and the second type by Wald (1944).

(A) *Discriminant function*

Suppose we have two groups of N_1 and N_2 individuals and upon each of which p measurements are available. We want to find a linear function from the set of observations which will discriminate the two groups. This is done by maximising the ratio of the differences between the means of two classes to the standard deviation within classes. Let the linear function be represented as

$$\alpha = \Sigma\, \lambda_i x_i, \qquad (i = 1, 2, \dots p) \qquad \text{... (2.14)}$$

The difference between the means of α and the variance of α within classes may be written as

$$D = \Sigma\, \lambda_i d_i \qquad (i, j = 1, 2, \dots p) \qquad \text{... (2.15)}$$

$$S_\alpha = \Sigma\, \Sigma\, \lambda_i \lambda_j S_{ij} \qquad \text{... (2.16)}$$

The particular function which will discriminate the two groups will be one for which the ratio D^2/S_α is the greatest by variation of the p coefficients $\lambda_1, \lambda_2, \ldots \lambda_p$ independently, i.e., for each λ

$$\frac{\partial}{\partial\lambda}\left(\frac{D^2}{S_\alpha}\right) = 0 \qquad \ldots \quad (2.17)$$

By solving the above equations λ's can be found out and hence we can find out the discriminant function. The next problem is to draw some conclusions from this derived function. We have defined the means of two groups as

$$\bar{\alpha}_1 = \sum_i \lambda_i \bar{X}_{1i}; \quad \alpha_2 = \sum_i \lambda_i \bar{X}_{2i}.$$

We want to test the hypothesis

$$H_0 : E(\bar{\alpha}_1) = E(\bar{\alpha}_2)$$

This is done by the usual F-test which is given as

$$F = \frac{N_1+N_2-p-1}{p}\,\frac{N_1\,N_2}{N_1+N_2}\,D \qquad \ldots \quad (2.18)$$

With degrees of freedom p and N_1+N_2-p-1..

(B) *Distance function.*

The same problem of classifying the two groups (so far their mean values are concerned) may also be solved by using D^2-Statistic. This has been discussed by Mahalanobis (1930), Bose (1934), and Roy & Bose (1939).

The definition and the sampling distribution of the studentised D^2 Statistic is given below.

$$\begin{aligned} p\,D^2_{rs} = {} & C^{11}(a^r_1-a^s_1)^2+C^{22}(a^r_2-a^s_2)^2+\ldots+C^{pp}\,(a^r_p-a^s_p)^2 \\ & +2C^{12}(a^r_1-a^s_1)(a^r_2-a^s_2)+\ldots+2C^{p-1,\,p}(a^r_{p-1}-a^s_{p-1})(a^r_p-a^s_p) \end{aligned} \qquad \ldots \quad (2.19)$$

Where C^{ij} is the minor of C_{ij} in the determinant $|C_{ij}|$ divided by the determinant itself.

$$\text{Const. } e^{-\frac{1}{4} p\,\bar{N}_{rs}\,\Delta^2_{rs}}(D^2_{rs})^{\frac{p-2}{2}}\left(1+\frac{p\bar{N}_{rs}}{2N}\,D^2_{rs}\right)^{\frac{-(N-k+1)}{2}}$$

$$ {}_1F_1\left(\frac{N-k+1}{2},\ \frac{p}{2},\ \frac{p^2\,\bar{N}^2_{rs}\,\Delta^2_{rs}\,D^2_{rs}}{8N+4p\bar{N}_{rs}D^2_{rs}}\right) d(D^2_{rs}) \qquad \ldots \quad (2.20)$$

When N is large, the above form reduces to

$$\text{Const } \bar{e}^{-pN_{rs}D^2{}_{rs}/4} \quad (D^2_{rs})^{\frac{p-2}{2}} \; I_{\frac{p-2}{2}}(p\bar{N}_{rs}\,\Delta_{rs}\,D_{rs}/2)d(D^2_{rs}) \qquad \ldots \quad (2.21)$$

The relevant statistical tables for testing the hypothesis of the equality of means have been constructed by Bose (1947, 1949). In this connection it may be mentioned that the compounding coefficients obtained after maximising the ratio (in Fisher's discriminant function) are really functions of the sample variance and covariances. Fisher has not explicitly calculated these coefficients, but a little algebra shows that after maximisation the ratio is proportional to D^2. Either of the two methods given above may be used for discriminating the two groups regarding their mean values.

In problems of discrimination we face a similar situation namely, discrimination between two groups regarding their variances and covariances which may be described as follows.

Suppose we have (i) two samples S_1 and S_2 of sizes N_1 and N_2 and variances and covariances a^1_{ij} and a^2_{ij} $(i, j, 1, 2, \ldots, p)$ drawn at random from two normal populations π_1 and π_2 with variances and covariances α^1_{ij} and α^2_{ij}, and *(ii)* k samples $S_1, S_2, \ldots S_k$ of sizes $N_1, N_2 \ldots N_k$, mean values $\bar{x}^1_i, \bar{x}^2_i, \ldots \bar{x}^k_i$ and variances and covariances $a^1_{ij}, a^2_{ij}, \ldots, a^k_{ij}$ drawn at random from k p-variate normal populations with mean values $\bar{\xi}^1_i, \bar{\xi}^2_i, \ldots \bar{\xi}^k_i$ and common set of variances and covariances α_{ij}. For (i) the null hypothesis associated with the process of discrimination in respect of the variances and covariances between the population π_1 and π_2 is $\alpha^1_{ij} = \alpha^2_{ij}$, and for (ii) the null hypothesis associated with the process of discrimination in respect of the mean values $\xi^1_i, \xi^2_i, \ldots \xi^k_i$ between the populations $\pi_1, \pi_2, \ldots, \pi_k$ is

$$\xi^1_i = \xi^2_i \ldots = \xi^k_i$$

For testing (i) and (ii) Roy (1939, 1942) has given sets of p-statistics which we designate as $k^2_1, k^2_2, \ldots, k^2_p$ and $t^2_1, t^2_2, \ldots t^2_p$. These are the p-roots of the determinational equation

$$\left.\begin{array}{lr} & \text{(i)} \quad | a^1_{ij} - k^2 a^2_{ij} | = 0 \\ \text{and} & \text{(ii)} \quad | a^*_{ij} - t^2 a^{**}_{ij} | = 0 \end{array}\right\} \qquad \ldots \quad (2.22)$$

Where a^*_{ij} and a^{**}_{ij} are quantities defined by

$$\sum_{r=1}^{k} (N_r - 1)a^r_{ij} = (N-k)a^{**}_{ij}$$

and

$$\sum_{r=1}^{k} N_r[(\bar{x}_i^r-\bar{x}_i)(\bar{x}_j^r-\bar{x}_j)] = (k-1)a_{ij}^{*}$$

$$N = \sum_{r=1}^{k} N_r \; ; \; \bar{x}_i = \sum_{r=1}^{k} N_r x_i^r$$

It has been found that both t_i's and k_i's have the same sampling distribution form under null hypothesis. The common form is given below

$$\text{Const.} \prod_{i=1}^{p} \frac{k_i^{N_1-p-1} dk_i}{\left(1+\frac{N_1-1}{N_2-1}k_i^2\right)^{\frac{N_1+N_2-2}{2}}} \times \left\{(k_1^2-k_2^2)\ldots(k_1^2-k_p^2)\,(k_2^2-k_3^2) \ldots(k_2^2-k_p^2)\ldots(k_{p-1}^2-k_p^2)\right\} \qquad \ldots \quad (2.23)$$

The relevant statistical tables for testing the two hypotheses have been given by Nanda (1951), Chaudhury (1956) and Pillai (1956). Thus we find that in the multivariate classification problem the discriminant function and the D^2 Statistics are useful for discriminating the two groups with respect to their mean values, the first set of p-statistics is useful for discriminating the two groups with respect to their variances and covariances, while the second set of p-statistics is useful for discriminating the k groups with respect to their mean values.

(C) *Wald's discriminant function*

It has already been stated at the beginning of the section that we often come across with the decision problem. This arises mostly in vocational guidance tests.

Let us consider two p-variate normal distributions π_1 and π_2 with mean values $(\mu_1, \mu_2, \ldots, \mu_p)$ and $(v_1, v_2, \ldots, v_p)$ and common variance and covariance matrix $\| \sigma_{ij} \|$. A sample of size N_1 is drawn from π_1 and a second sample of size N_2 is drawn from π_2. Let z_i be a single observation of the i-th variate drawn from a p-variate population π when it is known a-priori that it is either identical with π_1 or π_2. The set $(z_1, z_2, \ldots, z_p)$ is assumed to be distributed independently of $(x_1, x_2, \ldots, x_p)$ and $(y_1, y_2, \ldots, y_p)$. The statistical problem involved has been stated by Wald as follows :

"On the basis of the observations $x_{i\alpha}$, $y_{i\beta}$ z_i $(i = 1, 2, \ldots, p,\ \alpha = 1, 2, \ldots, N_1,$ $\beta = 1, 2, \ldots, N_2)$ we test the hypothesis H_1 that the population π from which the set $(z_1, z_2 \ldots z_p)$ has been drawn is equal to π_1. The parameters $\mu_1, \mu_2, \ldots, \mu_p, v_1, v_2, \ldots v_p$ and $\| \sigma_{ij} \|$ are assumed to be unknown. In this problem there exists only a single alternative hypothesis to the 0-hypothesis H_1 to be tested, i.e., the hypothesis H_2 that π is equal to π_2". The critical region for testing H_1 which is most powerful with respect to the alternative H_2 has been given by Wald as

$$U \geqslant d \qquad \ldots \quad (2.24)$$

where
$$U = \Sigma\,\Sigma\, S^{ij}\, z_i\,(\bar{y}_j - \bar{x}_j) \qquad \ldots \quad (2.25)$$

$$S_{ij} = \frac{\sum\limits_{\alpha=1}^{N_1} (x_{i\alpha}-\bar{x}_i)(x_{j\alpha}-\bar{x}_j) + \sum\limits_{\beta=1}^{N_2} (y_{i\beta}-\bar{y}_i)(y_{j\beta}-\bar{y}_j)}{N_1+N_2-2} \qquad \ldots \quad (2.26)$$

and d is chosen so that the critical region should have the required size.

It may be mentioned here that the statistics U is closely connected with the discriminant function.

We can look at the Wald's decision problem from another angle. The set of measurements z_i can be represented as a point in a p-dimensional space. Let us divide the space into two regions R_1 and R_2, if the point falls in R_1 we shall say it was drawn from π_1 and if it falls in R_2 we shall say it came from π_2. We have to select the two regions R_1 and R_2 such that the effect of misclassification is minimised on the average.

In problems of classification the statistician can commit two types of errors. Actually the individual may belong to π_2 while the statistician has classified him as coming from π_1 and vice versa. Let the 'Cost' of misclassifications be $C(1/2)$ and $C(2/1)$ respectively. The following table gives the cost of classification

		Population drawn from	
		π_1	π_2
Statisticians' Decision	π_1	0	$C(1/2)$
	π_2	$C(2/1)$	0

Cost can be measured in any units, as in the calculations we shall use the ratio of the two costs.

Let R denote the rule for classification. The probabilities for correct classifications are :

$$P(1/1,\ R) = \int_{R_1} p_1(z_1\, z_2 \ldots z_p)dz_1\, dz_2 \ldots dz_p \qquad \ldots \quad (2.27)$$

$$p(2/2,\ R) = \int_{R_2} p_2(z_1, z_2, \ldots z_p)dz_1\, dz_2 \ldots dz_p \qquad \ldots \quad (2.28)$$

and the probabilities for wrong classifications are

$$P(2/1,\ R) = \int_{R_2} p_1(z_1, z_2, \dots z_p)dz_1, dz_2 \dots dz_p \qquad \dots \quad (2.29)$$

$$P(1/2, R) = \int_{R_1} p_2(z_1, z_2 \dots z_p)dz_1\ dz_2 \dots dz_p \qquad \dots \quad (2.30)$$

If the observation is from π_1, there is a loss when observation is incorrectly classified as coming from π_2, the expected expressions for loss or risk are given by

$$r(1, R) = C(2/1)\ P(2/1, R) \qquad \dots \quad (2.31)$$

$$r(2, R) = C(1/2)\ P(1/2, R) \qquad \dots \quad (2.32)$$

i.e. the loss or risk is the product of cost of mistake and the probability of making it.

If q_1 and q_2 be the a priori probabilities of drawing the individual from the two populations π_1 and π_2 then the expected loss due to misclassification

$$q_1 r(1, R) + q_2\, r(2, R) = q_1\ C(2/1)\ P(2/1, R) + q_2\ C(1/2)\ P(1/2, R) \ \dots \quad (2.33)$$

We have to choose our regions R_1 and R_2 is such a way that this expected loss is minimised.

Anderson (1951) has discussed how the above principle can be utilised for (i) classification into one of two known multivariate normal populations, (ii) classification into one of two multivariate normal populations when the parameters are estimated, (iii) classification into one of several groups and (iv) classification into one of several multivariate normal populations.

Some applications of the principles enumerated above have been made by Tavers (1939), Rao (1948), Johnson (1950).

IV. MODEL STUDY

Psychometry deals with the measurements of human activities as its central theme. In Psychology we assume the presence of abilities as the primary causes responsible for the successful completion of a certain task. Thus we are assuming in a particular domain that the individual differences in accomplishments are due to these primary abilities. In mathematical symbols we may state

$$A_{\Omega}^{P} = F(a_1, a_2, \dots, a_k)$$

where A_{Ω}^{P} is a measure of accomplishment of any person P in the domian

Ω and $a_1, a_2, \ldots, a_k$ are the primary abilities or factors. In Psychometric models we attempt to give the functional forms which are consistent with the observed data.

Thurstone has given in simple language the main assumptions behind factorial investigations as follows :

"We proceed on the assumption that the mind is structured somehow, that mind is not a patternless mosaic of an infinite number of elements without functional groupings. In the interpretation of mind we assume that mental phenomena can be identified in terms of distinguishable functions, which do not all participate equally in everything that mind does".

The feelings of the statisticians about factor analysis or model studies have been depicted by Kendall (1950) in the following words:

"A feeling even exists among some statisticians that factor analysis is not really an accredited technique at all, that there is something unmentionable about its antecedents which put it outside respectable statistical usage. Other statisticians frankly admit that they know nothing about it in a tone of voice which indicates a feeling that an acquaintance with the subject is not a matter to be proud of". The misgivings of most of the statisticians about this method are due to the fact that very little applications of this technique has been made outside the domain of Psychology, though recently this technique has been utilised for solving certain problems in Econometrics. Accomplishment of any person in any test is denoted by a score. Thus a battery of n tests when applied to N individuals give rise to $N \times n$ score matrix. Our main object here is to represent these descriptive variables in terms of a smaller number of meaningful factors. This is accomplished by analysing the matrix of inter-correlations. For studying the models we shall consider two different situations, when Z_j's (set of descriptive variables) comprise all the data, i.e., they are not regarded as samples, and when they are regarded as samples. Corresponding to the two situations there will be two kinds of models.

(A) *Models of the first kind*:

(a) We can take a model with p components with no error or specific terms involved, which is called principal component model (p.c.m.); or (b) the model may be

$$z_j = \sum_{t=1}^{m} a_{jt} f_t + b_j s_j + c_j \epsilon_j \qquad \ldots \quad (2.34)$$

where a_{jt}, b_j, c_j are factor loadings; f, s and ϵ are common, specific and error factors. This is called multiple factor model (m.f.m.)

(B) *Models of the second kind* :

(a) The corresponding principal component model will be

$$z_j = \sum_{t=1}^{m} \alpha_{jt}\,\phi_t + \epsilon_j \qquad (j = 1, 2, \dots n) \qquad \dots \quad (2.35)$$

where ϵ_j is the error due to sampling and α's and ϕ's are considered as parameters of population; the problem then is to estimate α and ϕ; or (b) the corresponding m.f.m. can be stated as

$$z_j = \sum_{t=1}^{m} \alpha_{jt}\,\phi_t + \beta_j\sigma_j + k_j\epsilon_j \qquad \dots \quad (2.36)$$

here α, β, k are factor loadings, ϕ, σ are normal statistical variates. In this case our object is to estimate α, β and k, but not ϕ and σ.

Preleminaries

In the first kind of models enumerated above there are more parameters than variables. It is, therefore, impossible to estimate the parameters without making certain assumptions. The usual assumptions are as follows:

(a) common, specific and error factors are independent among themselves; (b) common factors are independent of either specific or error factors; and (c) specifics are independent of errors.

The above models are acceptable only when they can satisfactorily explain observed human behaviour. It is a matter of common experience that among properly constructed tests, scores are positively correlated. Scores are the external manifestations of human behaviour. Thus the question arises as to how nearly the correlations reproduced from a model or factor pattern should fit the observed correlations.

Having found out the rank and communalities in a correlation matrix we have to estimate the factor loadings and factors in different models. We shall consider the two types successively.

(A) *Models of the first kind.*

(a) The principal component model (p.c.m.) was developed by Hotelling (1933, 1936). We have seen that the communality of a test is the sum of squares of the common factor loadings. In the present analysis we have to choose factor in such a way that their contributions to the total communality will be in decreasing order of magnitude. Suppose there are m factors. We shall choose the factor loadings in such a way that the first factor F_1 has as large a variance as possible; we shall then choose the second factor F_2 so as to be independent of the first and to have as large a variance as possible; and so on. In this way we arrive at the approximate reduction of descriptive variables. It may be that the first one or two factors will account for 90% of the variance then we will neglect the remaining factors.

Let us take a typical equation as

$$z_j = a_{j1}F_1 + a_{j2}F_2 + \dots + a_{jm}F_m \qquad \dots \quad (2.37)$$

Then sum of the contributions of the first factor F_1 to the total communalities of n tests is given by

$$C = a_{11}^2 + a_{21}^2 + \dots + a_{n1}^2 \qquad \dots \quad (2.38)$$

We want to maximise C subject to the condition that the correlations are reproduced from the pattern, i.e.,

$$r_{jk} = \sum_{t=1}^{m} a_{jt}a_{kt} \qquad \dots \quad (2.39)$$

By using the method of Lagrange's multipliers the set of equations for the solution of unknowns a_{j1} may be written as

$$\begin{aligned} (h_1^2-\lambda)\, a_{11} + r_{12}a_{21} + r_{13}\, a_{31} + \dots + r_{1n}a_{n1} &= 0 \\ r_{21}\, a_{11} + (h_2^2-\lambda)a_{21} + r_{23}a_{31} + \dots + r_{2n}a_{n1} &= 0 \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots & \qquad \dots \quad (2.40) \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots & \\ r_{n1}a_{11} + r_{n2}a_{21} + r_{n3}a_{31} + \dots + (h_n^2-\lambda)a_{n1} &= 0 \end{aligned}$$

The necessary and sufficient condition for the system of equations to have a solution is

$$\begin{vmatrix} (h_1^2-\lambda) & r_{12} & r_{13} \dots r_{1n} \\ r_{21} & (h_2^2-\lambda) & r_{23} \dots r_{2n} \\ r_{n1} & r_{n2} & r_{n3} \dots (h_n^2-\lambda) \end{vmatrix} = 0 \qquad \dots \quad (2.41)$$

The largest root λ_1 of the characteristic equation, when substituted in the set of equations gives solution for $a_{11}, a_{21} \dots a_{n1}$. Having determined the coefficients a_{j1} the next problem is to find out a second factor which will account for a maximum of the residual communality. In order to do this it is necessary to obtain the residual correlations. This process has to be repeated till a considerable portion of the variance is explained.

Hotelling (1936) has given an iterative method which gives the roots of the characteristic equation and the factor loading for principal component model simultaneously.

(b) The multiple factor model may be stated as

$$z_j = \sum_{t=1}^{m} a_{jt} f_t + b_j s_j + c_j \epsilon_j \qquad \ldots (2.42)$$

Here we have to find out the coefficients a_{jt}, b_j and c_j.
We know that with a particular reference frame the factor loadings are the projections of the test vectors on the frame. So we can represent the n tests by means of n points in m dimensional space

$$P_1(a_{11}, a_{12}, \ldots a_{1m});\ P_2(a_{21}, a_{22} \ldots a_{2m}),\ \ldots P_n(a_{n1}\ a_{n2} \ldots a_{nm}).$$

Let us take the reference frame in such a way that the first axis passes through the centroid of the set of n points $P_1, P_2 \ldots P_n$. Then the m values of the co-ordinate are $\frac{1}{n}\Sigma\, a_{j1}, 0, 0, \ldots, 0$. With m.f.m. model the reproduced correlations will be

$$r_{jk} = a_{j1}a_{k1} + a_{j2}\, a_{k2} + \ldots + a_{jm}a_{km} \qquad \ldots (2.43)$$

Summing for all variables in a particular column

$$\sum_j r_{jk} = a_{k1} \sum_j a_{j1} + a_{k2} \sum_j a_{j2} + \ldots + a_{km} \sum_j a_{jm} \qquad \ldots (2.44)$$

Taking the sum of all correlation coefficients in the correlation martix

$$\sum_k \sum_j r_{jk} = \sum_m \Big[\sum_j a_{jm} \Big]^2 \qquad \ldots (2.45)$$

Under the particular set up of the reference frame given above

$$\sum_k \sum_j r_{jk} = \Big(\sum_j a_{j1}\Big)^2 \qquad \ldots (2.46)$$

and

$$\sum_j r_{jk} = a_{k1} \sum_j a_{j1} \qquad \ldots (2.47)$$

Substituting the value of $\sum_j a_{j1}$ in (2.47)

We have

$$a_{k1} = \frac{\sum_j r_{jk}}{\sqrt{\sum_j \sum_k r_{jk}}} \quad (k = 1, 2, \ldots, n)$$

Thus the centroid factor loadings for the first factor can be found out by dividing the sum of correlation coefficients in a particular column by the square root of the sum of all correlation coefficients. The next problem is to find out the second factor loadings for n tests in $(m-1)$ space which will be orthogonal to the first. The procedure is to form a residual matrix $\| r_{jk} - a_{j1} a_{k1} \|$. The centroid method cannot be applied to this matrix as the sums of the rows and columns are zero. This is overcome by 'reflecting' certain correlations and hence reflecting the residual vectors so as to produce a new cluster. The same process can now be continued until m components are found out or the residuals become insignificant at an earlier stage.

It has already been stated that factor loadings are the projections of the test vectors on the reference frame; so if we take different sets of reference frames we will get different values of the projections and hence the set of values for the factor loadings will be different. It will be apparent from this that while factorising a given correlation matrix it is possible to get an infinite number of pattern matrices. In order to make it in some sense unique Thurstone has laid down certain principles. These are known as the 'Principles of simple structure'. To arrive at a simple structure we have to rotate the axes several times. Mathematically the transformation is effected as follows:

$$M = AT \qquad \dots \quad (2.48)$$

where $A = \| a_{js} \|$ is the Original pattern matrix

$M = \| b_{js} \|$ is the final pattern matrix

$(j = 1, 2, \dots n;\ S = 1, 2, \dots m)$

and

$$T = \left\| \begin{matrix} \lambda_{11} & \lambda_{12} \cdots \lambda_{1m} \\ \lambda_{21} & \lambda_{22} \cdots \lambda_{2m} \\ & \\ \lambda_{m1} & \lambda_{m2} \cdots \lambda_{mm} \end{matrix} \right\| \quad \text{is the transformation matrix}$$

λ's are the direction cosines of the final reference axes $M_1\ M_2 \dots M_m$ with respect to the original axes $F_1, F_2, \dots F_m$. For more than two dimensions, rotational problems become very complex. In that case it is better to take two factors at a time and adjust the axes till we arrive at a simple structure.

(B) *Models of the second kind.*

$$\text{(a)} \quad z_j = \sum_{t=1}^{n} \alpha_{jt}\, \phi_t + \epsilon_j \qquad (j = 1, 2, \dots n) \qquad \dots \quad (2.49)$$

$$\text{(b)} \quad z_j = \sum_{t=1}^{m} \alpha_{jt} \phi_t + \beta_j \sigma_j + k_j e_j \quad (j = 1, 2, \dots n) \qquad \dots \quad (2.50)$$

In the first type both α_{jt}, ϕ_t are treated as parameters to be estimated. The residuals ϵ_j are assumed to be independent random errors which are normally distributed about zero means.

In the second type ϕ_t, σ_j are treated as independent normal variates with zero means and unit variances while α_{jt}, β_j are parameters to be estimated. The first type has been discussed by Young (1941), Bartlett (1937) and Whittle (1953), while the second type has been discussed by Lawley (1940, 1953).

Whittle (1953) has stated the advantage of the first type as follows: "the advantages of this view point are : (1) it is no longer necessary to form any priori assumptions concerning the factor values, (2) genuine statistical techniques may be applied, the whole sampling problem becoming much more direct and (3) sample estimates of the factor values may be obtained, and if desired even the individual residuals after fitting may be calculated." Lawley's (1953) observations are : "Both models are of interest. It should be emphasized, however, that they lead to somewhat different methods. If, as is usually the case in psychological problems specific factors are assumed to enter into the scheme of things, the second model would appear to be most appropriate. The psychologist is usually interested not in the individual values of ϕ_t but in the loading and in the structure of the correlation and covariance matrix".

(a) In the first type we shall consider the estimation of factor loadings and factor values in which the residual variates may be considered to have zero means and equal variances, so that the residual sum of squares is given by

$$U = \sum_j \sum_i \; (z_{ji} - \sum_t \alpha_{jt}\phi_{it})^2 \qquad \ldots \quad (2.51)$$

Under certain assumptions we shall arrive at the characteristic equation and the usual solution for λ's. Full discussion of this method for the estimation of loadings has been given by Whittle (1953).

(b) Lawley has discussed the second model in two important papers (1940, 1953).

In the first paper he assumed a factor pattern as

$$z_i = \lambda_i f + \mu_i g + \ldots + \nu_i h + \tau_i s_i, \qquad (i = 1, 2, \ldots t) \qquad \ldots \quad (2.52)$$

where $f, g, \ldots h$, $s_1, s_2, \ldots s_t$ are independent normal variates and $\lambda_i, \mu_i \ldots \nu_i, \tau_i$ are the factor loadings.

This is similar to the second type, the common factors only are separately stated as $f, g, \ldots h$.

The population variances and covariances $\{C_{ij}\}$ of the t tests are

$$C_{ij} = E\{(z_i - \xi_i)(z_j - \xi_j)\} \qquad \ldots \quad (2.53)$$

We may write

$$C_{ij} = \lambda_i\lambda_j + \mu_i\mu_j + \ldots + \nu_i \nu_j \qquad \ldots \quad (2.54)$$

$$C_{ii} = \lambda_i^2 + \mu_i^2 + \ldots + \nu_i^2 \qquad \ldots \quad (2.55)$$

The population parameters are unknown and have to be estimated from the available data.

The parameters can be estimated by maximising log L, where the likelihood function L is given by

$$L \propto \frac{| a_{ij} |^{\frac{1}{2}(n-t-2)}}{\Delta^{\frac{1}{2}(n-1)}} \exp\left[-\frac{(n-1)}{2\Delta} \sum_{i,j} (\Delta_{ij}, a_{ij})\right] \quad \ldots \quad (2.56)$$

Lawley has stated that though this method does provide in general an efficient set of estimates, it is by no means obvious nor easy to prove. He gave another method of estimation of factor loadings when either the values or the ratios of σ are assumed to be known where σ is the residual variance. In either case he supposes that the units of measurements are chosen in such a way that σ_j^2 are equal to σ^2 say. The two alternatives are then either that σ^2 is known, or that it is unknown and has been estimated from the data. The method involves an iterative solution of the estimation equations. The solution sometimes gives unacceptable solution.

(C) *Estimation of factors*

The problems of estimating factors for (A, b) and (B, a) models have been considered by several workers.

For Psychometric studies the model (A, b) is more important than (B, a); therefore, we shall discuss the method of factor solutions for (A, b). The factor solutions for (B, a) have been obtained by Whittle (1953).

Let us assume that a set of n tests variables $(z_1, z_2, \ldots z_n)$ has been analysed in terms of m common factors $(F_1, F_2, \ldots F_m)$ and n unique factor $(U_1, U_2, \ldots U_n)$. Then the factor pattern in matrix notation may be written as

$$\boldsymbol{Z} = \boldsymbol{MF} \quad \ldots \quad (2.57)$$

Where column vectors

$$\boldsymbol{Z} = \{z_1\, z_2 \ldots z_n\} \quad \ldots \quad (2.58)$$

and

$$\boldsymbol{F} = \{F_1, F_2, \ldots F_m U_1, U_2, \ldots U_n\} \quad \ldots \quad (2.59)$$

represent the test variables and factors and

$$\mathrm{M} = \left\| \begin{matrix} a_{11} & a_{12} \ldots a_{1m} & a_1, 0, 0, \ldots 0 \\ a_{21} & a_{22} \ldots a_{2m} & 0 \quad a_2, 0, \ldots 0 \\ a_{n1} & a_{n2} \ldots a_{nm} & 0, \quad 0, \quad \ldots a_n \end{matrix} \right\| \quad \ldots \quad (2.60)$$

represent the loadings.

We have to estimate the factors from the equations of the following type

$$\bar{F}_s = \beta_{s1} z_1 + \beta_{s2} z_2 + \ldots + \beta_{sj} z_j + \ldots + \beta_{sn} z_n \quad \ldots \quad (2.61)$$

Where D_{ss} is the minor of the first element and D_{js} is the cofactor of t_{js} in D. Here

$$D = \begin{vmatrix} 1 & t_{1s} & t_{2s} & \cdots & t_{ns} \\ t_{1s} & 1 & r_{12} & & r_{1n} \\ t_{2s} & r_{21} & \cdot & & r_{2n} \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ t_{ns} & r_{n1} & r_{n2} & & 1 \end{vmatrix} \qquad \ldots \quad (2.62)$$

Thus when the factors are uncorrelated the matrix equation for the prediction of the entire set of factors becomes

$$\bar{F} = M'R^{-1}Z \qquad \ldots \quad (2.63)$$

The above equation can be solved easily by using Aitkin's method of 'Pivotal Condensation'. Regression coefficients can be obtained very easily from correlation matrix. Vide Bose (1946).

Concepts about Tests of Significance in factor analysis are still in a very diffused state. In factorial work the problem of significance is essentially a problem of 'goodness of fit'. We have already seen that the factors which give closest fit to the $n \times N$ table of test measurements are also the factors which give closest fit to the $n \times n$ table of inter-correlations. In different models in factorial analysis we continue to extract factors till the residual correlation matrix becomes statistically insignificant. Thus we have to devise a statistical test with which we shall be able to examine the residual matrices.

Ordinary types of investigations seldom require a very precise test of statistical significance. Some sort of approximate method is sufficient, if it can suggest the stage at which we are to stop factorising. Chi-Square test with Z-transformation is suggested for this purpose.

Sometimes an investigator desires to know whether a given test is worth retaining or whether the difference of the factor saturations between two tests are statistically significant. For these purposes we need the standard error of each of the factor saturation. Lawley (1949) has developed a formula for the variance of a factor saturation,

$$\sigma_{ia} = \frac{\theta\alpha}{N}\left\{ 1 - \sum_{j=1}^{j=a} \theta_j f_{ij}^2 + \tfrac{1}{2}\, \theta_a\, l_{ia}^2 \right\} \qquad \ldots \quad (2.64)$$

where N is the number in the sample, f_{ij} is the factor saturation for test i in factor j, $\theta\alpha = 1 + \frac{1}{v_a^2}$ and v_a^2 is the variance for a, the factor in question and l_{ia} is the saturation of test i with factor a.

A detailed discussion on the test of significance in factor analysis has been given by Burt (1952).

So long we have considered the case of orthogonal factors, but sometimes we make use of oblique or correlated factors also. It is true that a certain simplicity of interpretation is sacrificed when we give up the assumption of orthogonality, but this disadvantage may be offset, however, if the linear description of variable is made simpler. An oblique solution for factor pattern may be obtained by means of rotation of some orthogonal pattern obtained by some of the methods given above. In case of estimation of factor, the estimating equation will be

$$\breve{F} = \Phi M' R^{-1} Z \qquad \ldots \quad (2.65)$$

where

$$\Phi = \begin{Vmatrix} \phi & 0 \\ 0 & I \end{Vmatrix}$$

and

$$\phi = \begin{vmatrix} 1 & r_{F_1F_2} & \ldots r_{F_1F_m} \\ r_{F_2F_1} & 1 & \ldots r_{F_2F_m} \\ r_{F_mF_1} & r_{F_mF_2} & \ldots \quad 1 \end{vmatrix}$$

The method of factor analysis has raised some doubts in the minds of experimental psychologists. The question that often confronts them is "what is the use of estimating man's factor at all". Though it is difficult to answer the above question within this short compass, still the following remarks will help considerably in understanding the aim of factorisation.

Thomson has described in clear terms the real advantage of factorisation. "Factorisation, if achieved, would react on social problems somewhat in the same way as the introduction of coinage influences trade previously carried on by barter. A man can exchange directly five cows for so many sheep, so much cloth and a new ploughshare, but the transaction is facilitated if each of these articles is priced in pounds, shillings and pence, even though the end result is the same. And so perhaps with the "pricing" of each man and each occupation in terms of a few factors. But the prices must be accurate and the analyses of tests and occupations into factors, still more the calculation of quantitative estimates of these factors are as yet very inaccurate and perhaps are inherently subject to uncertainty. A fluctuating and doubtful coinage can be a positive hindrance to trade and barter may be preferable in such circumstances".

(D) *Use of models in Econometrics*

The concept of factor analysis is now utilised in other branches of science. Specially in Econometrics this method is being increasingly used. Here we are citing an example from a paper by Tintner (1946). The example deals with an attempt to determine the principal components of a set of production indices. There are four indices; X_1, and index for the production of manufactured durable goods, X_2 of nondurable manufactured goods, X_3 of minerals and X_4 of agricultural products. The correlation matrix is given below.

TABLE 7 : A CORRELATION MATRIX OF INDUSTRIAL INDICES

	X_1	X_2	X_3	X_4
X_1	1.0000	—	—	—
X_2	.4959	1.0000	—	—
X_3	.8728	.7683	1.0000	—
X_4	.4812	.7098	.7124	1.0000

The four variables can be analysed into principal components or factors.

$$K_{11} = 0.8174,\ K_{21} = 0.8881,\ K_{31} = 0.9519,\ K_{41} = 0.8188$$

Hence it follows that the first principal component explains about 67 per-cent of the variance of the 1st variate, about 79 per cent of the variance of the 2nd variate, about 91 per cent of the variance of the 3rd variate and about 67 per cent of the variance of the 4th variate.

(*E*) *Stochastic models for learning.*

We define learning as the systematic change in behaviour. We consider it to be complete when it attains certain kinds of stability. Observations on animal and human learning present peculiar difficulties to the statistician. Organisms that can be considered identical at the start of the experiment do not remain so in the course of the experiment. Statisticians have attempted to describe the behaviour pattern by means of Stochastic models. The problem can be explained with the help of a simple experiment. Suppose we have a big T-rod with boxes at the two ends of theT. We place some quantity of food always at the right hand box and the left hand box is always empty. A rat is allowed to run from the base of the *T*-scale. If it goes to the right it gets the food and if it goes to the left it does not. After several runs it learns to turn right at the junction point. The observations that we record for a single rat are a sequence of left and right turns and our problem is to analyse this sequence. A simple probability model can be constructed from the behaviour of the rat. On each trial the rat either can go to the right or left ; let the probability be p_n that the rat goes to the right on n-th trial ($n = 1, 2, 3, \ldots$). For the first trial the rat has no preference so we may assume $p_1 = 0.5$. At subsequent trials we expect the rat to go more to the right than left, and after a sufficiently large number of trials p_n will be very near to one i.e. the rat will always run to the right. The probability model that can be suggested may be of the type

$$p_{n+1} = p_n + a(1-p_n) \qquad \ldots \quad (2.66)$$

This is a stochastic model for a simple learning process. We have to estimate the parameter a.

We have considered changes in probability considering responses only but it is known that stimuli and responses are connected in a learning process. So it is instructive to set up a formal model connecting both stimuli and responses.

After obtaining the models we have to solve the general problem of estimating the parameters of the model from experimental data. The usual method for this is the 'Method of maximum likelihood". Finally we have to test the goodness of fit of a model to a particular data. This topic has been throughly dealt with by Bush and Mosteller (1955)

(F) *Computer model.*

Several investigators are using the principles of 'Information theory' in Psychometry. It is not yet possible to envisage whether this concept will prove useful to this particular branch of science. Cronbach (1954) has stated that the psychologists should be very cautious in applying this theory. Quastler's (1956) comments are "It is important to question the validity and usefulness of the information function before each new application. There are cases where the information function is definitely approximate and cases where it is certainly of no use; besides there exists an intermediate domain where the conditions for using information functions are neither quite right nor quite wrong". In the study of information transmission we deal with a table of joint probabilities for each input and each output. From this table we can study the relationship between input and output, channel capacity and other information measures. We define a "Computer" as anything that process information in a precisely defined way. Our problem here is to find out what computer model will produce data like those observed. The term computer model is used in a very general sense; it may be a set of equations, or it may be an apparatus. All that does matter is that it should serve as a frame work to organize past and future experience. In order to use the concepts of information theory we view man as an information handling device. We consider him as a device accepting some input which is a function of time say $f(t)$ and generating an output, also a function of time say $\phi(t)$. In various ways we want to estimate the rules which transform input into output i.e. $f(t)$ into $\phi(t)$.

(G) *Analysis of variance model*

Usual statistical tests, namely, t, F, χ^2 and others are often used in psychometry for solving ordinary problems of classification. Apart from these tests statistical designs are sometimes used to solve certain problems. These designs include, randomised block, latin square, complex factorial experiments etc. Analysis of covariance is also sometimes used.

CONCLUDING REMARKS

From the rough sketch attempted above, certain developments, quite important in themselves, have had to be excluded for lack of time and space. But even under this limitation, the sketch will nevertheless have served its purpose if it gave some glimpse, however partial and inadequate, of the important developments that are taking place in this particular branch of science.

Prof. R. C. Bose in his presidential address of this section in 1947 said,"The great contribution which statistics can make to progress and development in India will be limited only by the extent to which our organisers of science and industry succeed in establishing a fruitful co-operation between the experimenter and the applied worker on the one hand, and the theoretical and mathematical statisticians on the other". I feel that even after the lapse of ten years we have not been able to establish the co-operation which was referred to by Prof. Bose. In modern times, in any type of scientific endeavour co-operative effort is essential and it is more so in applied sciences like Statistics. But we still believe more on individual enterprise than on collective efforts. This mental attitude has to be changed if we want to make a real headway in the progress of statistical science.

Finally I would like to record my sincere appreciation of the honour which my colleagues in the Section of Statistics of the Indian Science Congress have bestowed on me by electing me to the presidentship of the Section.

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SECTION OF PHYSICS

President : Dr. K. R. Dixit Ph.D. (London), F.A.Sc .F.N.I.

Presidential Address

Semi-Conducting Cuprous Oxide

Introduction

Probably the first observation in the semiconductor field was made by Faraday[1] in 1839. He observed that silver sulphide has a negative temperature coefficient of resistance. The next significant discovery was made by Smith[2] in 1873, who observed that the resistance of selenium is reduced on exposure to light. In 1874 it was observed that contacts between certain materials could rectify. [3,4] The first photoelement of the barrier layer type was prepared from selenium by Adams[5] and Day in 1876. While continuing this work on selenium, Fritts[6] produced in 1883 the first large area dry rectifier. Thus the four properties of semiconductors, (1) Negative temperature coefficient of resistance, (2) Rectification, (3) Photoconductivity and (4) Photoelectromotive force, which we to-day consider as the fundamental properties of a semiconductor, were observed more than 70 years ago.

Sir Jagadish Chandra Bose[7], working in this very city, was the first to realise that semiconductor rectifiers-point contacts on galena, silicon carbide, tellurium and silicon—were good detectors of radio waves. The next contributions were (1) the development of the copper oxide rectifier photocell by Grondahl and Geiger[8] and (2) the almost parallel developments with selenium by Lange.[9]

The next period of intense active interest was the World War II. The catwhisker diode was revived and developed into an excellent radar detector. The subsequent announcement in 1948, by Bardeen[10] and Brattain, of the transistor, has led to great technical developments and the semiconductor electronics now rates as a major field of research.

Now turning to the theoretical aspect of the problem, we find that considerable progress has been made during the past few years in explaining rectification at a metal semiconductor contact. Wilson[11] presented a quantum mechanical model of the semiconductor in 1931; according to him the behaviour of semiconductors, is due to the electron energy band structure as affected by temperature and impurities. In 1939 three different but similar theories were put forward by Mott[12], Schottky[13] and Davydov[14] to explain the behaviour of the semiconductor rectifiers. According to Mott, 'Rectification results from a potential barrier at the contact which impedes the flow of current carriers. The width of the barrier is about 1000 A and the current produced by the tunneling of electrons is relatively unimportant'. According to Schottky this barrier 'is physical rather than chemical in nature'. In a physical blocking layer, the potential barrier results from a space charge layer in a semiconductor and the corresponding induced charge on the metal surface. These two charge distributions form a double layer which adjusts the potential of the semiconductor relative to the metal for equilibrium conditions. According to Davydov 'in view of the low density of carriers in semiconductors, the double layer must be at least 10000 A thick to produce an adequate effect'. Simple reasoning based on Poisson's equation led Davydov to conclude that most of the potential difference in such an arrangement would be spread out on the semiconductor side of the barrier. Since the penetration of such a broad potential barrier by electrons would be insignificant, the rectification is explained by applying the diffusion theory. Ten years later Fan[15] and Rose and Spenke[16] had to assume a chemical layer (a layer different from the rest of the oxide) to explain the current voltage relations obtained by them. Mott applied his theory to the cuprous oxide rectifier whereas, Schottky was primarily concerned with selenium. Mott-Schottky type of theory gives the main qualitative features of the current voltage characteristics of semiconductor rectifiers and their dependence on temperature. There are, however, several quantitative discrepancies.

It will thus be seen that although semiconductors have been used in several practical applications, the physical interpretation of the semiconducting phenomena is far from complete. For this reason the major current objective of the solid state physics research programme, concerns the study of the semiconducting systems. Having thus decided to study the semiconducting systems, which semiconductors should we choose? Here we should remember that the semiconductors of interest in the communication electronics are cuprous oxide, selenium, germanium and silicon. W. H. Brattain, one of the well-known workers in this field, in a lecture delivered before the Institute of Radio Engineers in 1955, explains the reasons why germanium and silicon were chosen by him and his colleagues for investigation. 'Silicon and germanium are elements, with a diamond like crystal structure and the atoms are bound together with simple forces of the covalent type. Their melting points are very high. Thus any sample rectifier formed at a high temperature is very stable at ordinary temperatures. Further it is possible with germanium and silicon to form substitutional solid solutions, in which impurities from the 5th column act as donors and impurities from the 3rd column act as accepters. Thus in the investigation of the complicated semiconductor phenomena which is very structure sensitive, it appeared best to concentrate on the two simple semiconductors, germanium and silicon, and try to understand them first'. He further adds that 'as compared with germanium and silicon, selenium is more difficult to study as it solidifies into complicated interlocking chains', but cuprous oxide again compared with germanium and silicon 'is a mess'. We have, however, been studying some aspects of the semiconducting cuprous oxide, with some measure of success for the last few years and I propose to give you a short resume of the work we have been doing.

CUPROUS OXIDE (PRELIMINARY REMARKS)

My interest in this problem started in 1930, when I was working in the laboratory of Sir George Thomson[17] in London. Murison[18] was investigating the structure of copper oxide formed in air between 300°C to 500°C in the same laboratory. I prepared cuprous oxide layers which acted as rectifiers, with a rectification greater than 50, and tried to study their structure by the method of electron reflection. I found that under the incident electron beam these blocks charged up and taking pictures was rather difficult. But whenever I succeeded in taking a picture I always saw two or three diffuse rings outside the shadow edge. The interpretation of these rings was still more difficult at that time (1931), and I had to reluctantly leave the problem at that stage hoping to return to it sometime later.

In 1939, after the publication of papers by Mott, Schottky and Davydov it became clear that impurities should play a dominant role in the semiconductor action. At that time it was a general belief that if impurities are present in the copper block on which the cuprous oxide rectifier is to be prepared the rectification is adversely affected. I was able to show that the rectification improves by a factor of three if a small amount of silver[19] is included in copper. Later on the effect of admixture of other metals with copper was investigated and in many cases it was found that the rectification improves. An Indian patent[20] was taken in 1942. At that time mixing a small amount of impurity to improve the rectification was a new idea. To-day, however, this doping technique has become the standard technique. The only other observation similar to ours made about the same time is that of Sharavskii[21].

In 1952, we were successful in building an electron diffraction camera with a fairly satisfactory performance and we decided to start again with the cuprous oxide problem. Without going into great experimental detail of our published work I propose to give an outline of the results we obtained and then give the conclusions we derived.

CUPROUS OXIDE (EXPERIMENTAL)

We have already reported the properties of oxides of copper formed at atmospheric[22] pressure and also at low[23] pressures. We find that at atmospheric pressure and low temperature a thin film of Cu_2O is formed. As the temperature and time of formation increases, the crystallites of Cu_2O increase in size and get oriented. With a further increase of temperature and time these crystallites of Cu_2O gradually change over to those of CuO, first showing a three ring pattern, then a definite orientation and finally a fibrous structure. At temperatures beyond 750°C and with a proper time of formation, it is possible for a Cu_2O film to be formed below the CuO film. Such a composite film shows considerable rectification. At 410°C and pressures upto 75 mm of Hg only Cu_2O can be formed. Oxides formed at pressures upto 5 mm of Hg and a time of oxidation sufficiently long show a peculiar undergrowth structure of Cu_2O in contact with the copper block. This oxide shows four, rather broad rings which approximately correspond to 111, 222, 333 and 444 rings of Cu_2O. But all these films showing the peculiar structure were too thin and did not show any electrical resistance or rectification.

In the light of these two observations of ours namely, the formation of a Cu_2 O film below a CuO film, the composite film showing rectification and the peculiar structure shown by the Cu_2O film formed at low pressures. And also in the light of the wellknown fact that the rectifying oxide of copper is formed at low pressure, at about 1000°C followed by a suitable heat treatment or annealing. We have studied the oxides of copper formed at an air pressure 0.5 mm of Hg in the temperature range 200°C to 1030°C and also the effect of the subsequent heat treatment on these oxides. (As this work is not yet published, a few more details are given). The following properties of the films so formed were investigated, their crystal structure by the method of electron diffraction and X-ray reflection, the thickness of the films formed and the change of crystal structure with depth, the resistance, rectification and magnetic susceptibility of the films. We also studied the variation of all these properties as a function of the temperature of formation of the films and their subsequent heat treatment.

We find that cuprous oxide films formed at 500°C just begin to show rectification, it becomes appreciable at about 800°C, afterwards this increases very rapidly with the temperature of formation. The appearance of an appreciable amount of rectification is accompanied by a peculiar change in the electron and X-ray patterns. The electron diffraction pattern is now characterised by the 222 ring of Cu_2O becoming broad and strong at the centre ultimately changing over to a four arc pattern showing four rather broad arcs which approximately correspond to 111, 222, 333 and 444 arcs of Cu_2O. The corresponding X-ray pattern is characterised by a weakening of the 200 ring which is normally strong and by an increase in the intensity of the 220 ring. This indicates a change of crystal structure accompanying rectification. The greater the magnitude of rectification more prominent becomes the change. It will be seen from table 1 that this redistribution of intensities, which incraeses at higher temperatures of formation of the film, and which indicates a change over to a diamond like structure, has just started at 900°C. The change indicated by X-rays, it should be remembered, is a change in the average crystallites present throughout the oxide.

TABLE 1

Specimen	Treatment	Relative intensity of X-ray reflection							Resistance		
		110	111	200	211	220	311	222	R_1	R_2	R_1/R_2
Pure Cu_2O Tablet	Prepared with a little gum tragacanth	20	100	61	(5)	32	25	5	..	..	..
Cu_2O film formed at 550°C	Slowly cooled in vacuum	20	100	60	(5)	31	25	5	22	11	2.0
700°C	,,	20	100	61	(5)	33	26	3	80	38	2.01
900°C	,,	15	100	(5)	(5)	50	30	5	1250	42	30.5
1030°C	,,	13	100	(5)	8	50	35	(5)	6600	88	75.0
1030°C	*Suddenly* cooled in vacuum	20	100	(5)	8	50	35	(5)	$\sim 10^5$	$\sim 10^5$	1.1
Diamond	A. W. Hull *Phys. Rev.* **10**, 66, (1917)	0	100	0.5	0	50	40	0			
Zincblende	W. Gerlach *Physik. Z.* **23**, 114 (1922)	0	VS	W	0	S	S	W			

The layer of rectifying Cu_2O is an insulating layer; it quickly charges up on exposure to an electron beam, and we have to be very careful in taking the electron reflection picture. In the case of films formed at 900°C the free surface gives with electrons a picture showing 111 orientation and rings with spots, indicating that large oriented crystallites of normal insulating Cu_2O are present in the free surface. While the layer at a depth of 1000 A shows a pattern of four rather broad arcs which approximately correspond to 111, 222, 333 and 444 arcs of Cu_2O. This indicates that rather small oriented crystallites of Cu_2O are present at this depth.

The average rectifier formed at 1030°C is about 90 microns thick. This film, if it is rapidly cooled, shows at the surface a layer of Cu_2O with large crystallites showing a 111 orientation and rings with spots. But during the process of slow cooling of this film, the topmost layer becomes very uneven, probably because of ejection of oxygen, and does not show any electron reflection pattern. When this topmost uneven layer (1000 A) is removed we begin to get an electron diffraction picture. Between 1μ and 80μ we see the four arc pattern indicating the presence of small crystallites of Cu_2O (as we shall see presently with an excess of oxygen), which have an orientation and which form a layer like structure. Now at 80μ we begin to see spots on rings, but these spots are elongated. The spots lie on rings of normal Cu_2O showing that the size of the crystals is now larger. The elongation of the spots is probably due to refraction. 222 ring of the four arc pattern persists, showing that large normal crystallites of Cu_2O are present side by side with small ZnS type of crystallites of Cu_2O. At 88μ copper rings begin to appear along with the normal Cu_2O rings and the four arc pattern has completely vanished. At 90μ depth we also see the elongated spots, but now they are present on the copper rings and not on the Cu_2O rings.

TABLE 2

Temp. of formation °C	Resistance of oxide films at 1.5 Volts. (D.C.)					
	Slowly cooled			Suddenly cooled		
	R_1	R_2	R_1/R_2	R_1	R_2	R_1/R_2
700	80	38	2.1	2000	1700	1.2
800	400	37	10.8	10000	8000	1.3
900	1250	41	30.5	42000	30000	1.4
950	3360	62	54.2	72000	54000	1.3
1000	6600	88	75.0	100000	90000	1.1
1030	8080	86	94.0	150000	135000	1.1

The slowly cooled and the rapidly cooled films show a remarkable difference in their resistance and rectification (see table 2), but they do not show any appreciable difference which could be definitely detected with electron or X-ray reflections. We, therefore, decided to investigate, the structural differences of the slowly cooled and the rapidly cooled films by the measurement of their magnetic susceptibilities. Our results are shown in fig. 1. It will be seen that as rectification increases the film becomes less and less paramagnetic and ultimately when rectification has increased appreciably it begins to show a definite diamagnetism. The maximum values of rectification are obtained for a rate of cooling of about 3°C per minute. Such films show a diamagnetic susceptibility of about minus 9×10^{-8} Further suitable heat treatment of these best rectifiers reduces their rectification and increases the diamagnetic susceptibility still further. At low pressures at which these layers are prepared, small crystalites of Cu_2O, containing a few extra oxygen atoms are formed. During the process of slow cooling most of the dissolved oxygen gas is ejected out. Assuming that the susceptibility of the solid solution is the sum of the susceptibilities of the two components Cu_2O and oxygen, we can calculate the amount of oxygen present per 100 molecules of Cu_2O. Fig. 2 shows the rectification as a function of the percentage of oxygen atoms present.

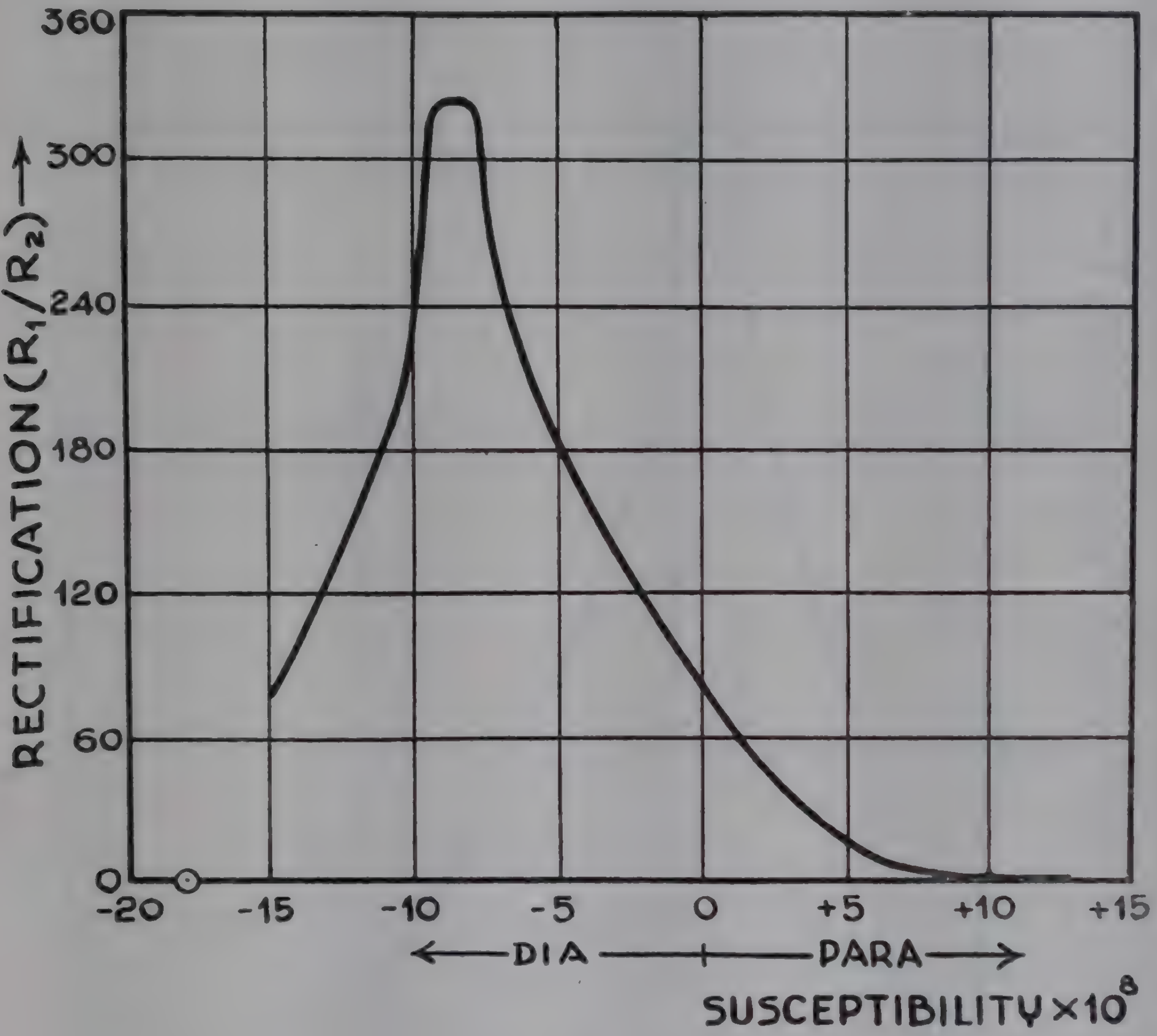

Fig. 1

Our experiments thus show that in the case of cuprous oxide rectifier we have in the rectifying layer a large number of small crystallites of Cu_2O. These Cu_2O crystallites show a structure similar to that of diamond or zinc blende. The rectifying crystals are diamagnetic.

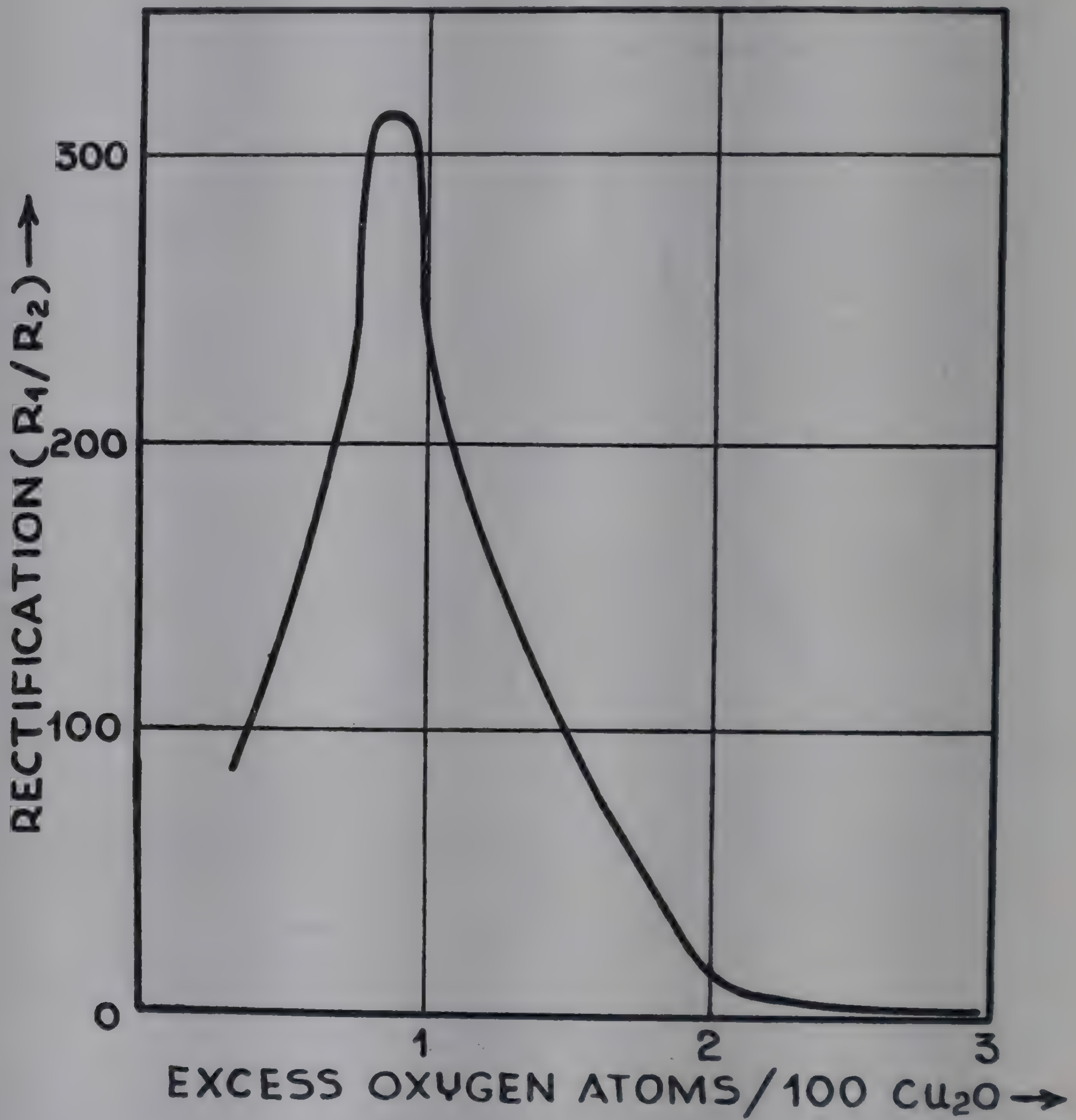

Fig. 2

Probable mechanism of formation of the rectifying layer

When a block of copper, heated to a sufficiently high temperature, was exposed to oxygen at low pressure (partial pressure of oxygen about 0.1 mm of Hg) we observed that a sort of instability sets in. in the crystallites of Cu_2O formed on the surface. The instability showed itself either in the form of a change of orientation (upto 550°C) or in the form of an increase in the size of the crystallites (above 550°C). For a temperature of formation of the film greater than 700°C, the crystallites in the surface show a 111 orientation and an increase in size. Because of this instability a few oxygen atoms or ions are able to diffuse through the interspaces between the crystallites present in the surface. A thin layer of oxygen will now be formed below the free surface and this will enable the new crystallites of Cu_2O to be formed (according to the migration theory of Mott[24] and Cabrera) below the old, oriented crystallites of Cu_2O present in the surface. We could reasonably expect from the laws of epitaxial growth, that the new crystals of Cu_2O, should have the same structure and the same orientation. But they are really growing on a thin oxygen layer formed on the oriented crystals of Cu_2O. The role of 111 orientation can be understood if we remember that the system of 111 planes in Cu_2O includes copper and oxygen atoms in alternate planes and this permits the inclusion of a few more oxygen atoms or a few less copper atoms in this system of planes. Further the 111 orientation is also helpful, because now the planes of oxygen atoms on which the epitaxial growth takes place becomes the virtual 111 plane of the new crystallites. Thus in this epitaxial growth the new crystal starts with an excess of oxygen atoms in the 111 plane. But this inclusion of a few more oxygen atoms in the 111 planes of a Cu_2O crystal virtually changes its structure to that of the diamond or the zinc blende type.

Based on our experiments we are now able to give the following picture about the formation of a Cu_2O rectifying layer. During the process of formation of a film of Cu_2O at low pressures and high temperatures, a definite number of extra oxygen atoms (very probably about 3) gets associated with a crystallite. This association gives rise to a modified form of crystal structure of Cu_2O, namely, a crystal structure of the zinc blende or the diamond type. During the process of annealing, the oxygen gas is gradually ejected out. This reduces the average number of oxygen atoms associated with a crystallite ($3 \rightarrow 2 \rightarrow 1$). The maximum rectification is obtained, when one atom of oxygen (of course as an average) is associated with a crystallite of Cu_2O. (The average size of the rectifying Cu_2O crystallite was determined from the width of the rings in the four arc pattern). A further reduction in the amount of oxygen reduces rectification, till we reach the stage of zero oxygen atom associated with a crystallite. This,of course, is the stage when we have pure Cu_2O which as is well known, is not a rectifier. It is significant to note that when we succeeded in removing all the oxygen from the rectifier film, by suitable heat treatment, the substance was no longer a rectifier, and the crystal structure as shown by electrons changed back from the zinc blende pattern to the normal Cu_2O pattern.

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SECTION OF CHEMISTRY

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PRESIDENTIAL ADDRESS

"INDIA'S CONTRIBUTION TO INORGANIC CHEMISTRY"

I find from a perusal of the Presidential Addresses to the different sections of the Indian Science Congress during the last few years that it has been the custom to show courtesy to those who have elected the Presidents. I follow with pleasure this traditional practice and offer my most sincere and grateful thanks to the members of the sectional committee and the executive of the Indian Science Congress Association for electing me to preside over the deliberations of the Chemistry Section this year. In making this choice I take it that they have honoured and recognised the growing importance of the branch of Chemistry in which I have specialised viz. Inorganic Chemistry. For, I know that there are a few chemists who should have preceded me in this office. This high honour and privilege of the office of the President is associated with great responsibility. I am quite conscious of my limitations but with your co-operation and help I hope to discharge my duties satisfactorily and carry through the work of the Chemistry Section to a successful end.

The Chemistry Section came into existence with the Science Congress in 1914 in Calcutta and the first session was presided over by the late Acharya Prafulla Chandra Ray the great *savant* and father of chemical research in India. He inaugurated an era of modern chemical research in India with his discovery of mercurous nitrite. The chemical research in India thus began with Inorganic Chemistry. At the first session of the Chemistry Section only eight papers were presented. This number has now increased to 322. This represents a good record but obviously it is not good enough when compared with that in countries like America, Germany and England. To-day we are passing through a different phase in Chemical research. Due to the recent developments of nuclear fission and atomic power Inorganic Chemistry has again come into the front position. In 1938 Sir J. C. Ghosh in his Presidential address to the Science Congress at Lahore referred to the question "what has happened to Inorganic Chemistry in India" because until then and for a long time thereafter the field of chemical research was taken up by Organic Chemists and Physical Chemists at one time or other. To-day we need more persons trained in methods of research in Inorganic Chemistry for the growing needs of the Department of Atomic Energy, the National Laboratories, Universities and industry. If you count the top ranking chemists in the fields of Organic or Physical Chemistry you will be able to count many. But in Inorganic Chemistry the situation is different. You will find that the number is very small. Even in the recently developed field of Biochemistry you will get sufficient number. Truly then we can repeat the question "what has happened to Inorganic Chemistry in India"? Perhaps many a chemist thinks it to be an unprofitable field for investigation. Or else it is the one neglected in our Universities and Research Institutions. Let us all be aware of this.

When the question of selection of a topic for my address to you to-day came up before me I thought I could speak on a branch of research in which I have devoted my years of work or speak on the subject of modern interest such as the rare-earths, co-ordination compounds, tracer technique and the like. But on second thought I was convinced that the former will have a very limited appeal and the second would be somewhat like an essay of an advanced student of Chemistry. I decided to take up for the subject of my address a topic of general interest and such as would lay emphasis on what is needed in our country to-day. I, therefore, propose to speak to you for a while on "India's contribution to Inorganic Chemistry". This topic to my mind is a homage to the late Acharya P. C. Ray with whom the modern chemical research in India began and who started it with a subject in the branch of Inorganic Chemistry. I was not fortunate to have been a pupil of Acharya P. C. Ray but I have drawn inspiration from his work and from my association with him when he visited Bombay—I was for many years Secretary of the Bombay Branch of the Indian Chemical Society. On one occasion when Acharya Ray was on his visit to Bangalore via Bombay he told me "My young friend! My days are numbered: it is for you young men to carry on the work I have begun". These words are still ringing in my ears. Let us honour his memory by proving ourselves worthy of his expectations.

The contribution of a country to a given field of Scientific activity can be judged either from the volume of original research publications or from outstanding achievements. The former does not give a complete picture because a good amount of original work often remains unpublished. The latter only gives land-marks on the road to progress. I have attempted to find out how the volume of published research work in the field of Inorganic Chemistry in India has fluctuated from time to time. This has been represented graphically in figure 1.

It is seen that there are fairly wide fluctuations in the volume of published work. However, it is gratifying to note that there is a steady upward trend. The two peaks reflect the world upheavels in 1914 and 1939. The first one has preceded the first World War while the second has followed the Second World War. The next upward trend seems to be connected with the First Five Year Plan. I do not claim exactitude for the points on the curve. For, it is difficult now-a-days to define precisely the sharp boundaries of Inorganic Chemistry. The curve gives an over-all picture of the general increase showing also years in which the publications have been considerably limited. There are many factors which are responsible for these ups and downs. I will refer to them later in my concluding remarks. It would be interesting to have similar curves for the different branches of Chemistry.

Now turning to the main theme of my address I propose to deal with the subject under the headings: 1. Inorganic Chemistry in Ancient India; 2. Nineteenth century; 3. The first two decades of the twentieth century; 4. The next two decades (1921-1940) and 5. Fifteen years upto 1955. In compiling the information and preparation of nearly a thousand reference cards from the literature I have been assisted by my students, Dr. S. R. Patel, Dr. Miss Lily B. Desai, Dr. Miss S. R. Dalal and Miss S. C. Saraiya, Shri B. G. Joshi, Shri P. K. Kapadia and Shri V. K. Kabir. My grateful thanks are due to them all.

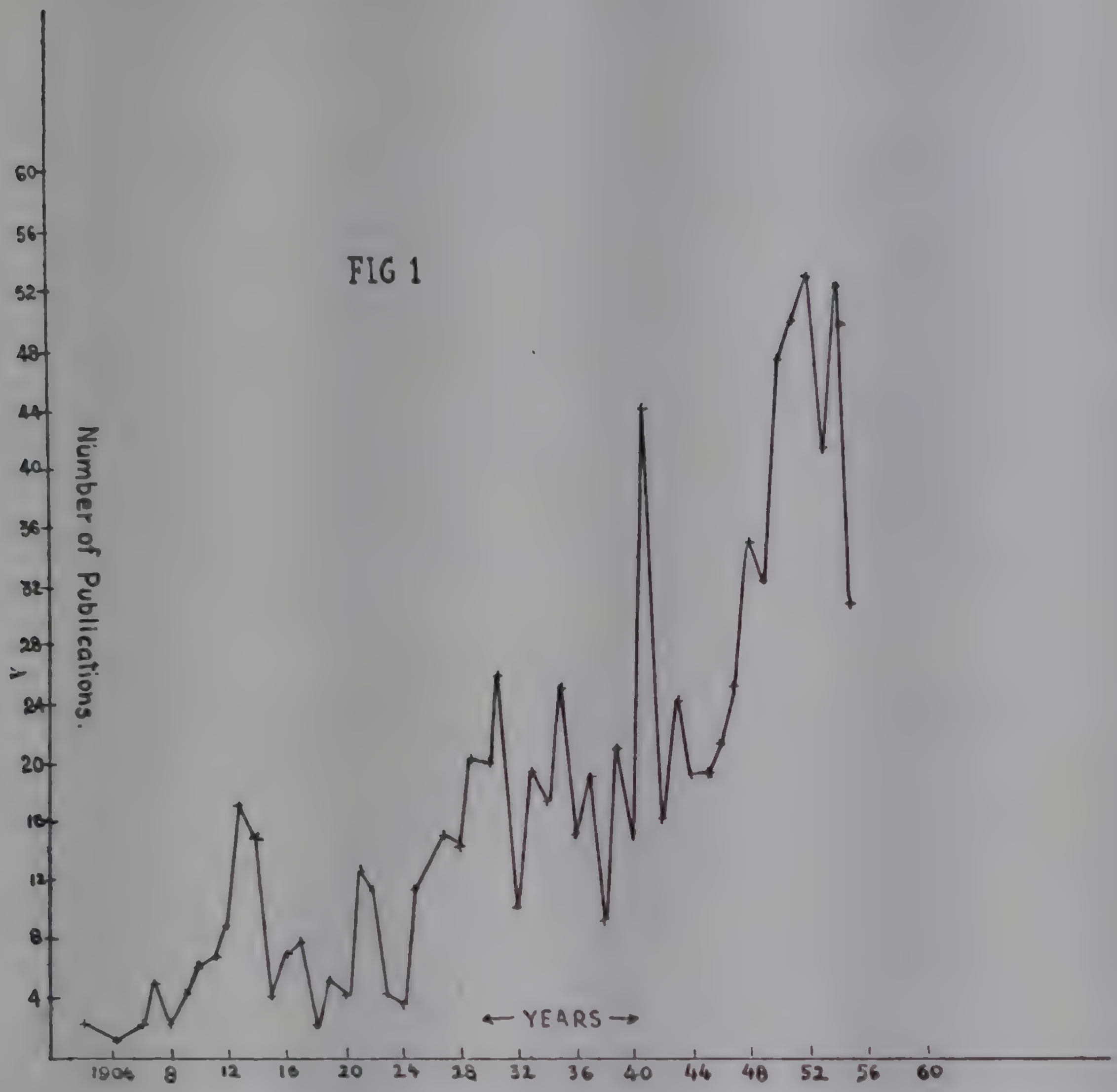

FIG 1

1. Inorganic Chemistry in Ancient India

This aspect of my theme is to be found ably treated in the masterly work "History of Hindu Chemistry" by Acharya Sir P. C. Ray. I will take up only a few relevant portions from this work to show that India has contributed to the knowledge of Inorganic Chemistry since very ancient times. Gold and silver were not only known in the Vedic Period but were worked into ornaments. The warriors of old were protected with coats of mail and helmets of metal. Besides gold and silver several other metals e.g. iron, lead and tin are mentioned in Yajurveda. In the Charaka we find mention of some metals and their calces and in Susruta we have the preparation and use of alkalies and alkaline caustics. Alkalies are described as of two sorts: for external application and internal administration. But more systematised knowledge of Inorganic Chemistry began with Vagbhata.

According to one evidence Vagbhata flourished 'At least as early as the second century before Christ'. In his treatise Astangahridaya, he refers to the use of minerals and natural salts in medical prescriptions and also gives the use of a few metallic preparations which would presuppose an advanced knowledge of Chemical processes. In the Brihatsamhita of Varahamihira (587 A.D.) there is mention of iron and mercury among the aphrodisiacs and tonics. Since the days of Vagbhata and Varahamihira metallic preparations had begun slowly to creep into use and at the time of Chakrapani (1050 A.D.) and his predecessor Vrinda they had so fully established their claims that from the 10th century onward every medical work recommended compounds of metals which could have been prepared only by a synthetic method. The knowledge of practical chemistry prevalent in India in the 12th and 13th centuries A.D. and earlier is distinctly in advance of that of the same period in Europe. It was known for instance that blue vitriol and a variety of pyrites yielded an essence in the shape of copper. Similarly Calamine gave zinc. The colour of flames as a test of metals was well understood (Rasarnava).

We thus find that Inorganic Chemistry gradually developed as a science in India from the Vedic times. At the beginning of the 16th Century A.D. the Portuguese had established themselves in India and at this time not only metallurgical operations and preparations of salts but preparations of mineral acids by distillation were known (Rasapradipa, about 1535 A.D.). In the 17th and 18th Centuries much progress does not appear to have been made. This is partly to be attributed to the unsettled state of affairs and lack of security in the country resulting from repeated foreign invasions and constant changes in Government.

2. NINETEENTH CENTURY

The revival of the study of sciences in India began with the foundation by Sir William Jones of "The Asiatik Society" in 1784. There were activities in different subjects such as Zoology, Botany, Anthropology, Mathematics, Physics, Meteorology and Chemistry. But the first paper of research work on an Inorganic Chemical subject was communicated from "Chemical Laboratory Presidency College, Calcutta" and published in Zeitschrift für Anorganische Chemie of 1896, vol. 12 by P. C. Ray. It is entitled "Über Mercuronitrit". He discovered that dilute nitric acid in contact with mercury at about 30°C gives fine yellow needles of mercurous nitrite. He thus laid the foundation of a new era of chemical research in India. A year later two papers appeared from the same laboratory by Jyotibhushan Bhaduri on "Conversion of hypochlorites into chlorates" by the action of chlorine on solutions of sodium hydroxide under different conditions, and on the "Decomposition of mercurous chloride and the estimation of free chlorine". Towards the end of the 19th century one more paper by Chandrabhushan Bhaduri and Jyotibhushan Bhaduri appeared on the double thiosulphates of copper and sodium. They observed that the colour of the salts depends on the ratio of sodium thiosulphate to the copper sulphate, the concentration of the solutions and the presence of alcohol. In this way a good beginning was made. These researches were on more conventional lines and showed the capacity of Indians to do original work in the fields of chemical research.

3. THE FIRST TWO DECADES OF THE TWENTIETH CENTURY (1901-1920)

In this period the most prolific contributor to our knowledge of Inorganic Chemistry is Acharya P. C. Ray with his band of coworkers. He and his collaborators have nearly 35 papers on the chemistry of nitrites of different metals dealing with their thermal decomposition, reactions and physical properties as also on some complex nitrites including a study of their behaviour towards alkyl iodides. A set of 6 papers from the same source deals with a study of hyponitrous acid and hyponitrites of alkali metals, mercury, silver and calcium as well as preparation of tetramethyl ammonium hyponitrite by the inter-action of silver hyponitrite with tetramethyl ammonium iodide. Other papers by Acharya P. C. Ray and his students include those on mercuri-ammonium salts, their preparation and properties, the interaction of mercuric and cupric chlorides with mercaptan and of the former with thio-compounds to yield mercuric sulphoxychloride. There is also a paper by P. C. Ray in which he has discussed the place of mercury in the Periodic Table. It is in the first decade that P. C. Ray with A. C. Ghosh made a beginning of his studies of platinum compounds. It was shown that ammonium platinic chloride decomposes when heated according to the equation $3(NH_4)_2PtCl_6 = 3Pt + 16\ HCl + 2NH_4Cl + 2N_2$ and that the di-imide is not formed. The corresponding bromide decomposes in the same way but partly with the liberation of bromine.

In the two decades under consideration N. R. Dhar and his coworkers take the second place. But the number of papers from this school deal with a study of physio-chemical properties such as the effect of catalysts on the reactions between inorganic compounds and electrical conductivity measurements to distinguish a double and a complex salt. From the purely Inorganic Chemist's view point there are two papers—one on alterability and instability of cobaltammines and the other on the constitution of chromic acid. Among other inorganic chemists of this period we have (1) P. Neogi with papers on the reaction of nitrous acid and amines, on a new method of preparing mercurous iodide and two other papers on the reduction of Fehlihg's solution to copper and reactions in the presence of nickel ; (2) K. Bhaduri on complex compounds containing copper, on the decomposition of nitroprussides by reagents and two other papers on the action of chlorine peroxide on ethyl alcohol and sodium silver thiosulphate and acetylene silver acetilide ; (3) R. C. Ray who began his work on boron hydrides and related compounds ; (4) P. R. Ray published a paper entitled "the action of hydrazine and hydroxylamine on ferricyanides and a method for the estimation of hydrazine" with H. K. Sen in Zeit. anorg. Chem. in 1912 and (5) R. L. Datta published papers dealing with double halides of Ag Pt Pb Cu Hg and Cd particularly compounds containing metal iodides and a paper on zincoso-zincic-chloride. The other researches in Inorganic Chemistry of this period are concerned with different topics making about 20 papers and they are mostly from Bengal.

THE NEXT TWO DECADES (1921-1940)

At the commencement of this period India had just recovered from the mild shock of the first World War. The importance of the development of scientific knowledge was realised and we find that in the period of these twenty years considerable progress was made. While most of the work in the preceding two decades was done in Bengal other centres of research came into being and got activated. There are in all about 385 papers on the subjects of Inorganic Chemistry. The most outstanding contributions are from three Rays, Panchanan Neogi, P. B. Sarkar and Dunnicliff. On the Bombay side we find for the first time papers on Inorganic Chemical subjects. Among them mention may be made of the contributions of Mata Prasad, M. S. Shah and S. M. Mehta.

Acharya P. C. Ray continued to be active worker with his students and associates. Out of about 45 papers the important ones are on (a) varying valency of Platinum and Gold with respect to mercaptanic radicals ; (b) New kind of complex Platinum compounds with tervalent and quinquivalent platinum ; (c) Complex compounds of iridium with ammonia, ethylamine, organic sulphides or pyridine ; (d) complex mercury ammonium and chromium ammonium compounds ; (e) a new series of double sulphates of Cu-Mg group and the sulphonium bases and (f) different complex compounds.

P. Neogy carried out resolution of some co-ordinated inorganic compounds into optical isomers such as triethylene diamino zinc chloride and sulphate. He also prepared some new compounds of gallium and gave their properties. Not only this he succeeded in the resolution of complex oxalato gallium compounds into optical isomers. His other work includes (i) a study of induction in chemical reactions; (ii) use of Mg-amalgam in the reduction of nitrites, nitrates, nitric acid and salts of oxycids of sulphur. He has about 17 papers during this period.

N. R. Dhar has about the same number of papers more or less of the physico-chemical nature. But there are a few papers on the subject of Inorganic Chemistry such for example as "New views on the constitution of chromic acid", cobaltammines, action of nitric acid on metals and action of metals such as Cu and Zn on aqueous solution of ammonium nitrite.

R. C. Ray continued his work started in the earlier decade on boron compounds and did work specially on the hydrolysis of magnesium boride. He also worked on the ternary systems KBF_4-$KI0_4$-H_20; KBF_4-$KMn0_4$-H_20 and KBF_4-$KClO_4$-H_2O.

P. R. Ray with his collaborators has during this period done comparatively very large amount of work in the field of pure Inorganic Chemistry. He has during this period about 51 papers to his credit. His important contributions relate to (a) Isolation of isomeric thiosulphuric acids by the hydrolysis of isomeric $H_4((CN)_5CoS_20_3)$; (b) Preparation of hexa-co-ordinated complexes of the composition $(M(N_2H_4)_3)S_2O_3$; (c) a number of complex compounds containing cobalt; (d) compounds of hexamethylene tetramine with salts of silver and other metals as well as with complex cobalt salts; (e) use of quinaldinic acid, rubeanic acid, hexamethylene tetramine and other complex compounds as analytical reagents specially for microchemical tests; (f) biguanidine complexes containing Cr, Cu, Co, Ni and other metals; (g) complex iodates of Sn, Sb, Pb and Ti.

P. B. Sarkar interested himself on compounds of gadolinium, europium, scandium and rare-earths. During his studies of the triple nitrites of rare-earths he found a new micro-test for caesium. He has also a few other papers on complex compounds of chromium and amino acids and a series of new tetramine cobaltic complexes.

The publications of H. B. Dunnicliff and his collaborators include (a) action of hydrogen sulphide on nitric oxide, on solutions of nitric acid, chromic acid, chromates and dichromates; (b) action of bromine on strontium oxide and its hydrates; (c) Volumetric determination of mercury and also the determination of free mercury in commercial products; (d) the determination of potassium in the presence of sulphates (M. A. Hamid); (e) equilibrium in the system H_20-$KN0_3$-$Ca(N0_3)_2$.

S. M. Mehta's papers from Bombay include (a) conditions for the existence of sodium zincate; (b) reaction between mercuric chloride and solutions of phosphates and (c) behaviour of cobaltous oxide on heating.

In addition to the above publications there are a few papers by S. Ramchandran on the action of hydrochloric acid on bismuth sulphide and on the reduction of $CuSO_4$ by sodium hypophosphite. Moreover there are nearly 140 papers by different investigators indicative of the fact that during the two decades under review researches in the fields of Inorganic Chemistry had been started at places other than Bengal.

FIFTEEN YEARS UPTO 1955

Now we embark on a period of activity in the field of Inorganic Chemistry not surpassed before. This period is conspicuous in the history of our country on account of the effects of World War II and the freedom of our country. The torch of chemical research in India lighted by Acharya Prafulla Chandra Ray kindled many others first in Bengal and then throughout India. In the period under review, therefore, we find active centres of research not only in Bengal but in places like Lahore, Banaras, Bombay, Bangalore and Madras. The volume of published work is comparatively very large, there being not less than about 500 papers on original work. In writing this review I feel like the abstractor of Acharya Ray's early paper on "Mixed double sulphates of Cu-Mg group" published in 1889 who said "of the mass of details of which this paper consists it is impossible to make an abstract". In spite of this I will attempt to indicate the salient features of this period of a decade and a half. In doing this it is impossible to do justice to all. If I fail to mention names of any research worker it is not due to less importance of the work but rather because it would be unfair to those of my listeners who have interests elsewhere than in Inorganic Chemistry.

Prof. P. R. Ray continued to work with the same or rather increased vigour. Papers from his school are about 28. They include : (a) further work on biguanidine compounds specially preparation of compounds of biguanidine with bi- and trivalent metals, resolution of cobaltic trisbiguanidine complex into its optically active enantiomerides, copper, and nickel biguanidines and their different modifications and use of this reagent in analytical chemistry, (b) study of the chemistry of rhenium, niobium and tantalum, (c) a new type of complex silver compounds with trivalent Ag ; (d) Cystine as an analytical reagent for Cu, Cd, Co, Ni and Zn ; (e) preparation of some polymolybdates and their constitution ; (f) On tetrapositive nickel as alkali nickel periodates.

Prof. S. M. Mehta and his school of workers have about 26 publications which include : (a) a series of papers on double sulphates of the type $RS0_4.M(S0_4)_2$ where R=bivalent metal and M=tetravalent metal and of the type $RS0_4.Ti0_2.S0_4$; (b) recovery of titania from the bauxite sludge and titaniferous materials and the preparation of titania pigments ; (c) isolation of the zincates of sodium and potassium ; (d) a useful buffer mixture ; (e) sodium perborate as an oxidising agent ; (f) preparation of ammonium sulphate and sodium bicarbonate from sodium sulphate ; (g) determination of Cu, Cu0 and Cu_20 in a mixture ; (h) study of the reaction between sodium phosphate and mercuric salts.

At Banaras we have G. S. Deshmukh and his collaborators working on problems in analytical chemistry including use of diphenylcarbazone for colorimetric determination of germanium, iodimetric determination of uranium, estimation of red phosphorus by potassium bromate, estimation of thorium by selenious acid and a new volumetric method of cerium determination. His other papers include ammonium sulphate as a flux for ilmenite, metal tellurates and interaction of nitrous oxide, nitrogen and phosphorus under silent electric discharge.

In Hyderabad we have D. S. Datar and his coworkers who carried out investigations on the reactions of chromates at high temperatures including synthesis and decomposition of chromates of alkaline earths. Other publications from this centre are on industrial chemistry side including preparations of manganese sulphate from pyrolusite, KOH from feldspar and on the preparation of Na_2S from Na_2C0_3 and pyrites.

There are comparatively fewer research workers on rare-earths. In Andhra we have S. V. Raghav Rao and in Calcutta Nihar K. Dutta working on the methods of separation and estimation of elements of this group.

From Allahabad there are a series of papers on the uses of adsorption indicators for different estimations by R. C. Mehrotra and others.

Mention may be made of the contributions of A. K. Dey, A. K. Bhattacharya and A. K. Majumdar. The first one has papers which include investigations on the formation of complex stannic oxalates, extent of inhibition of the precipitation of stannic sulphide in the presence of tartrate, oxalic acid and oxalates, the preparation and properties of argentothiosulphate complexes and on the existence of hexammine cupric sulphate. The second one has worked on ferro and ferricyanides while A. K. Majumdar's papers include uses of quinaldic acid, 2-picolinic acid, benzene arsonic acid, quinoline-8-carboxylic acid, biguanidine sulphate and dimercapto thiodiazole as analytical reagents. The above is only a brief review. I have not included research work contained in nearly 330 papers, and I apologise to the authors whose names have not been mentioned above. This is because the time at my disposal is limited. Each one has played and is playing his role in the advancement of our knowledge.

CONCLUDING REMARKS

The New Era of scientific research and development was inaugurated with atomic explosions of 1945. These explosions have been followed by a number of experimental ones each proving to be better than its predecessor. The terms hydrogen bombs and thermo nuclear reactions and the like have become common. With these developments researches in the field of Inorganic Chemistry have taken a new turn. Newer methods of chemical analysis, newer techniques in synthetic methods and preparations of inorganic materials of exceedingly high degree of purity have been developed. We now-a-days talk of particles smaller than the atom. The atom is composed of protons, electrons, and neutrons. There is still search being made of the fundamental particle. The work on the nuclear fission has led not only to the liberation of vast amount of energy, but has also led to the synthesis of new elements. We have the transuranic series with plutonium, neptunium and others. Inorganic chemistry of today is not only concerned with the preparations and properties of new compounds and complex molecules but also with this new synthesis of newer atoms. The dream of the alchemist of the transmutation of metals has been realised. I think at not very far distant date it may become possible to condense the fundamental particles to give desired elements. For, we have now a more or less complete picture of the atom and the molecule. These are dynamic entities. The atom has movements of neutrons and electrons inside the limited space. In the molecule there is an organisation which is dynamic and stable but not capable of regenerating itself. With the living cell we have an organised group of atoms synthesised into complex molecules which are also dynamic but capable of reproducing their kind. There is thus a gap between the non-living and the living which remains yet to be filled up. We have the fundamental particles, atoms and molecules leading to the living cell.

In spite of the upward trend in the research publications in India as shown in figure 2 we are still not keeping pace with the progress in more advanced countries. Our researches are still on conventional or orthodox lines. There is increasing demand for trained Inorganic Chemists for the Department of Atomic Energy, the National Laboratories, the Universities and Industry. We do not have enough number. I know of many posts being advertised and readvertised more than once. This is due to different factors. Among them may be mentioned, first of all, want of encouragement to young workers and setting before them instances of senior workers who are almost overcome with a sense of frustration.

If the enthusiasm and energy of the young workers are not harnessed for the progress of our country now the opportunity may be lost for many decades. The State Governments do not seem very much alive to this. But the Universities are trying to do their best. The latter can train people and give facilities for research. The employment of the trained research men and their proper status and emoluments are matters for the Government and Industry. Another factor of importance is personalities. Acharya Prafulla Chandra Ray set an example by creating a school of research workers with himself as the dynamic nucleus. In the field of Inorganic Chemistry who are others who have come up to a high position and formed themselves as nuclei of different centres of research work? We find such individuals mostly in Bengal. Examine other centres of research and you will find very few names. It is but obvious that the Inorganic Chemist has not been fortunate or forceful to make the authorities take note of his needs and ideas. In Bombay for instance all past Presidents of the Chemistry section have been Organic Chemists—Dr. K.

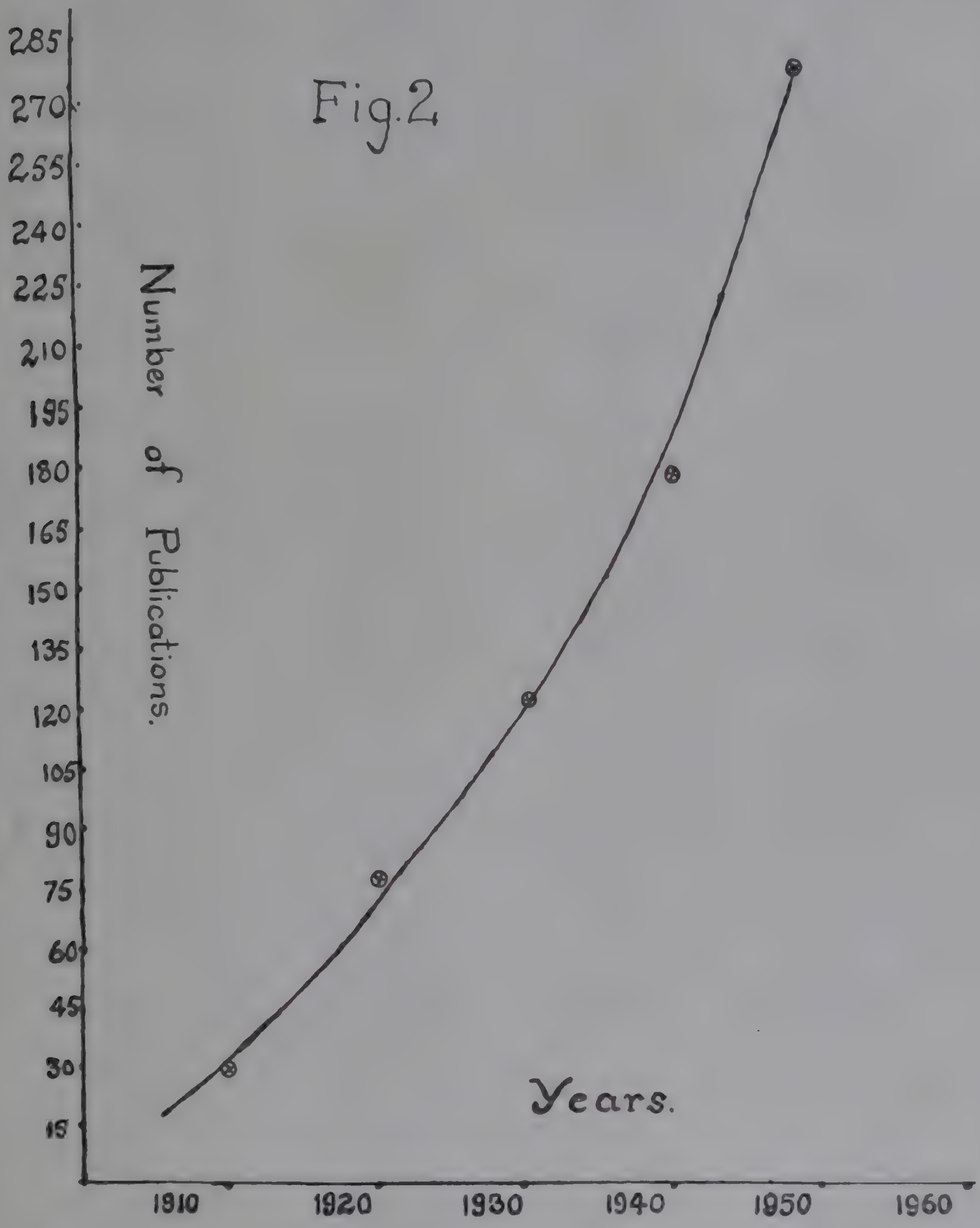
Fig.2

G. Naik, Dr. K. Venkataraman, Dr. R. D. Desai and Dr. R. C. Shah with the exception of Dr. Mata Prasad.

I have referred earlier in my address to the factors which account for the ups and downs in the curve of research publications in Inorganic Chemistry given in figure 1. Apart from the two factors mentioned above viz. encouragement to research workers and personalities there are two more. They are facilities and media for publication. As regards facilities for research they have varied from time to time but in recent years we have ample facilities for those who desire to work: the deficiencies can be overcome with some effort. As regards media for publication we have many difficulties. The noted periodicals such as the Journal of the Indian Chemical Society, Proceedings of the Indian Academy of Sciences, Journal of Scientific and Industrial Research, Current Science, Science and Culture are a few channels. These are not enough nor are they as efficient as similar periodicals in other countries. Something should be done in this connection so that there is speedy publication of results of research work already done. Otherwise there is danger of it remaining unpublished and being lost.

Our country is independent today. The period of the First Five Year Plan is over and we have commenced the Second Five Year Plan. There are better opportunities now available to Indians than ever before. But no progress worth the name is likely to result in the scientific development unless we chemists make our presence felt and known to the administrators. The starting of National Laboratories is not the solution. The administrator must take into confidence a few chemists and give them the position they deserve. Some of you recollect the days when the lead to the University Education in Calcutta was given by Sir Ashutosh Mookerjee who undaunted by opposition, worked hard to raise the Calcutta University to the present position it occupies. I think we have today a personality in Sir J. C. Ghosh, a member of the Planning Commission to whom we can look up to start the drive and play a rôle similar to that of Sir Ashutosh. I am also sure that with the sympathy and foresight of our Prime Minister Shri Jawaharlal Nehru for scientific development we can be optimistic. Let me conclude with the story of a little naughty girl who desirous of improvement went to the church with her parents and prayed "Oh, God! I am naughty and mischievous: Kindly improve me". "But", she continued, "if *you* fail, try, try again!"

SECTION OF GEOLOGY AND GEOGRAPHY

President :—Dr. B. C. Roy, D.I.C., M.Sc. (Lond.), Dr.-Ing. (Freiberg)

PRESIDENTIAL ADDRESS

GEOLOGICAL SURVEYS AND MINERAL EXPLORATIONS IN NATIONAL PLANNING

I. Introduction

My first duty is to thank you most cordially for the great honour you have done me in electing me to this chair. Many eminent geologists have filled this chair in the past with signal distinction. I cannot claim any such distinction, but I shall try my best to justify the trust reposed in me.

In view of my long association with the field of geology, both abroad and in India, with 20 years of work in connection with geological mapping and mineral surveys with the Geological Survey of India, I naturally decided to address you on the subject of 'Geological Surveys and Mineral Explorations in National Planning'.

The industrial progress of the western countries has been largely due to the application of modern scientific knowledge in various fields of science and industry, and the important role played by geologists, geophysicists, mining engineers and metallurgists in their development has been significant.

Most of the important countries of the world have their geological surveys with modern equipment and research laboratories, and employ trained geologists, geophysicists, chemists, mining engineers, etc. In addition, some countries have private firms and organizations undertaking mineral explorations and mineral research. The world's first official Geological Survey Department, namely, that of Great Britain, was established in 1835. The other older Geological Surveys are those of Canada (1842), Spain (1849) and India (1851).

The primary function of a National Geological Survey is the preparation of accurate geological maps which not only depict the rock types and their geological structures, but also help in the location of mineral deposits. They are invaluable in the solution of problems of ground water resources, soil study, location and design of dams and other engineering projects. As such, the Geological Surveys continue the basic mapping in addition to other studies in connection with engineering geology, ground water problems, geological and geophysical prospecting, drilling and explorations. Their work is intimately linked to the mining, metallurgical and chemical industries.

In my Address, I have given an outline of the organization and the field of activities of certain important Geological Surveys and related institutions of the world, which I had the privilege to visit in recent years. I refer to the Geological Surveys of the U.S.S.R., United Kingdom, France, West Germany, East Germany, Algeria, Tunisia and Japan. It may be of interest to fellow geologists in our country to know about the role played by the Geological Surveys of these countries in their national progress. There are certain aspects affecting administration and practice in these countries which we might emulate to our advantage. The Soviet Geological Survey is dealt with in some detail as we have no published information regarding its recent set up and activities.

I have dealt with the activities of the Geological Survey of India which is going to play a dominant part in the future economy of the country. The Geological Survey's plan of work and expansion has been outlined and it is high time that we should review our problems with the country's leading geologists, with a view to formulating plans and means for rapid mineral development in India. The Geological Survey during its existence of a century had set up a high standard of work both in quality and quantity, and its publications enjoy an international reputation. With the beginning of the second century, under the inspiration of a National Government, the Geological Survey's scope and responsibilities are now greater and its policy has to be re-oriented or reviewed. I have made certain proposals in this connection.

In all the countries I have visited, the geologist is consulted in the field of exploration, mining and civil engineering schemes at various stages of planning and designing. He is given adequate facilities to arrive at a definite opinion, which is the influencing factor of the development at all stages. A great responsibility is thus imposed upon him and he has proved his mettle by hard work and devotion to duty. In India, the value of a geologist and an official Geological Survey is not understood by the public, and those in authority have been slow in realizing their importance.

While India's mineral wealth had remained largely unexplored in the past due to lack of rapid industrialization of the country, the mineral wealth of the U.S.A., Canada, U.S.S.R., Western Europe, North Africa and Japan, has been and is being increasingly explored, leading to the present premier position of these countries in the domain of mineral industry and national economy. However, the country is now on the verge of launching a programme of country-wide industrialization as envisaged in the second Five Year Plan, and the demands upon our natural resources are bound to expand considerably. Some of the highlights of the Plan in the domain of mineral industry are as follows:—62 per cent increase in the production of coal, 42 per cent in manganese-ore, 150 per cent in cement, 190 per cent in iron-ore, 258 per cent in steel ingots, 415 per cent in aluminium, and 205 per cent in gypsum.

The Industrial Policy Resolution of 1956 envisages three categories in the field of industrial development. New industrial units in the first category (coal, oil, iron, manganese, chrome ore, gypsum, sulphur, gold, diamond, copper, lead, zinc, tin, molybdenum, wolfram and atomic energy minerals) will be developed exclusively by the State, and the industries in the second category (all other minerals except "minor minerals") will be progressively State owned. The remaining industries in the third category will be ordinarily open to the private sector. Private industry will have to adjust in the light of the above policy.

II. MINERAL RESOURCES AS A KEY TO INDUSTRIALIZATION AND RECENT TECHNIQUES IN EXPLORATION

The demand for minerals in the present industrial age has increased considerably, and it is said that the amount of mineral products consumed in the period between the two World Wars has exceeded the total consumption during the previous centuries, and it is no wonder that the world reserves of minerals are being progressively depleted. The fast depletion of the critical metals is causing concern to the highly industrialized western nations. The underdeveloped eastern countries, with poor consumption of metals, have been chiefly exporting their minerals to west.

The national security and prosperity of a nation depend largely on the availability of mineral resources. Dr. A. M. Bateman, in an Address before the Indian Science Congress in 1954, said that those who hold the purse strings of mineral resources hold power and those nations endowed with varied mineral resources became world's leading industrial countries like England, France, U.S.A. and U.S.S.R., politically and militarily strong ones.

No country is fully self-sufficient in mineral resources. There is an uneven distribution of minerals in the world and some countries are richer than others. Even the British Commonwealth, U.S.A. and U.S.S.R., although rich in many essential minerals, lack in many strategic minerals. Intensive mineral explorations, recent mining and technological advances, development of substitutes, conservation measures, etc., will help to augment the known world mineral reserves, but even then many countries must depend on ever increasing foreign mineral imports.

During World War II, the U.S.A. had to import some sixty-five different minerals, from fifty-three countries, twenty-seven originating from entirely foreign sources. The post-war demand for minerals in the State is equally great and is anticipated to be greater in the next 25 years. It has been recently estimated that out of 41 minerals required for industry and defence, 15 will last for half a century, 3 for 33-40 years, 20 for less than 25 years and 9 for less than 10 years. With regard to 8, no reserves are available.

Japan's industrial progress depends on the supplies of minerals from other countries, as the country has insufficient or poor sources of iron, coking coal, manganese, chromium, nickel, tungsten, cobalt, molybdenum, lead, bauxite, oil, etc. Japan like other industrial nations has become a great consumer of minerals.

Although not as rich as the U.S.A. or U.S.S.R., India's mineral position is not definitely poor. The country's basic mineral resources for industrialization consist of coal, iron, mica, manganese, gold, ilmenite and building materials. Sufficient reserves exist with regard to bauxite, clays, steatite, chromite, atomic energy and rare-earth minerals, limestone, dolomite, refractory minerals and abrasives. The country is poor in copper, lead, zinc, graphite and oil, and there is a permanent deficiency of nickel, cobalt, tungsten, molybdenum, tin, silver, platinum, mercury and sulphur.

Dr. D. N. Wadia, in his Presidential Address to the Mining and Geological Institute in 1952, has pointed out that India can, in future, supply iron and steel to Asian and European countries, and is capable of manufacturing for export a range of ferro-alloys, light metals aluminium and magnesium and other alloys, and titanium products in the sphere of promising major mineral utilization schemes. The less important mineral industries of the future would be the manufacture of alkalies and salts, chemical fertilizers, nitrate and phosphates, utilization of waste mica, by-products from coal, etc.

Dr. M. S. Krishnan has rightly remarked that hitherto in India conservation of minerals appeared to be nobody's business, and stressed upon the necessity of evolving a mineral policy towards that end. He again urged careful husbanding of India's mineral resources through conservation measures in his Presidential Address at the 43rd Session of the Indian

Science Congress. Mineral assets constitute non-renewable national wealth and thus the industry must be persuaded to eliminate all waste by improvement in mining technique, upgrading of poor quality ores, improved metallurgical practice and planned utilization of minerals.

In western countries recent advances on methods of mineral exploration and improved techniques on ore-dressing and metallurgy have brought about correct appraisal of mineral deposits and greater recovery of various metals as by-products from a single ore-body, hitherto rejected as mine dumps or lost as waste tailings.

The use of helicopters for rapid geological mapping is an accomplished fact and several surveys have been carried out in Canada and elsewhere with great success.

The use of geochemical prospecting, a cheap and rapid method, now adopted in the Geological Survey of India, should have large possibilities. Geo-chemical prospecting methods used in the U.S.S.R. cover litho-chemical, hydro-chemical, bio-chemical and atmo-chemical studies.

The use of air photographs and their interpretation, hitherto adopted in other countries of the world, have proved very useful in the Geological Survey's work.

Several countries, including well explored countries, are carrying out intensive large scale geological mapping and prospecting for discovery of new sources of mineral wealth using geophysical methods, airborne magnetometer surveys, deep drilling, etc., with a large measure of success. The recent discovery of new oil fields in Arabia, England, France, Holland and West Germany, is a pointer to this, and it is believed that new oil fields are likely to be located in some parts of the world including India.

Recent progress includes logging of bore-holes by mechanical, electrical, radioactive and other methods, for stratigraphical correlation, preparation of sub-surface maps, etc.

Airborne radiometric prospecting in recent years has increased the reserves of fissionable minerals in the U.S.A. In 1954, the number of private aircrafts used for such work in the State amounted to between 75 and 100. Radiometric prospecting for uranium ores by the Atomic Energy Commission is known to have proved successful in India.

III. GEOLOGICAL SURVEYS IN THE U.S.S.R., WESTERN EUROPE, NORTH AFRICA AND JAPAN

U.S.S.R.—In the U.S.S.R., until 1912, there were 15 to 20 geologists working under the Geological Committee set up in 1882. A Geological Prospecting Trust was created after the 1917 Revolution, which was subsequently reorganized into a Prospecting Department, and eventually in 1938 a Committee on Geology under the Council of Ministers was established. At the end of World War II, the Soviet Government felt the necessity to strengthen the geological service and set up a separate Ministry of Geology in 1946, the first Ministry of its kind to be set up in any country of the world. This was reorganized in 1953 as the Ministry of Geology and Conservation of Mineral Resources which is the highest body of the geological service in the Soviet Union. The total strength of the Ministry is 20,000, out of which 14,000 are geologists. The 1955 budget of the Ministry was of the order of 3,700 million Roubles.

There are also several other Ministries in the U.S.S.R., *e.g.*, Coal, Oil, Ferrous Metallurgy, Non-ferrous Metallurgy, Chemical and Building Materials, etc., which employ geologists with a view to carrying out detailed geological mapping of mineral deposits, prospecting, revision of ore reserves, hydro-geological studies, etc., as required for their specific purposes.

The Soviet Union covers some 22 million kilometers comprising about one-sixth of the land surface of the globe, and therefore, for efficient discharge of all geological work the Ministry functions through four Main Regional Geological Survey Departments and twenty-two Territorial Geological Departments. The Urals Geological Department, a typical Territorial Geological Department of the Main Geological Department of the Urals, covers an area of two million square kilometers of the Urals region and employs some 300 geologists. The region is one of the most important mineral-bearing areas in the U.S.S.R., where about 15 Geological Expedition Parties are now operating. The Department has its own laboratories, museums, libraries and workshops, and its main function is to conduct detailed systematic geological mapping of the territory, co-ordinate all geological data, publish geological maps of different scales and undertake detailed prospecting of all mineral deposits excepting oil and gas.

The Ministry of Geology and Conservation of Mineral Resources has also several special organizations as follows:—

(1) *Geophysical Department.*—Six Territorial Geophysical Trusts are responsible for undertaking geophysical surveys in close collaboration with the Territorial Geological Departments.

(2) *Department of Engineering Geology and Hydro-Geology.*—It includes All-Union Hydro-Geological Trust for survey of ground water resources and All-Union Aero-Geological Trust for aerial surveying and geological mapping of the inadequately surveyed and inaccessible areas.

(3) *All-Union Geological "Fund" (Central Bureau).*—Its main function is to assemble all geological data from the entire country for correlation and compilation work.

(4) *Scientific Research Institutes.*—Several research institutes, directly or indirectly connected to geological matters, work under the Ministry. The All-Union Scientific Research Institute in Geology in Leningrad, the Scientific Research Institute of Arctic Geology, the Institute of Hydro-Geology and the Caucasian Institute of Mineral Raw Materials are particularly worthy of mention.

(5) *Manufacturing Plants.*—The Ministry maintains several plants for the manufacture of drilling and mining equipment, geophysical instruments, outfits, etc., which are supplied to the Territorial Geological Departments and the Expedition Parties, through the Department of Technical Supply.

In the Soviet Union, there are special bodies called the Territorial Commissions on Mineral Reserves which are independent of the Territorial Departments. Their main function is to check over the reliability of the data on geological prospecting carried out by the Territorial Geological Departments. In addition, there is a State Commission on Mineral Reserves working directly under the Council of Ministers. It checks up the estimates on reserves, judges the degree and reliability of the geological studies, determines the suitability of opening up of the deposits, opines on the utilization of all mineral components and guides the Territorial Commissions. In the U.S.S.R., no mineral deposits can be opened up unless the reserves are thoroughly checked and confirmed by the State Commission on Mineral Reserves.

Geological mapping in the Soviet Union is done according to a definite plan, with an ever increasing detail. Special tectonic, structural and palaeogeographical maps are also prepared. Mapping on scales of 1 : 10,000 to 1 : 5,000 usually follows in case of detailed prospecting of ore deposits.

The 1 : 10,000 scale is generally employed in case of large sedimentary ore deposits or large deposits of igneous origin. Detailed mapping on scales of 1 : 5,000 to 1 : 2,000 is required to delineate the ore-bodies and to study the structure of the ore zones, but mapping on a scale of 1 : 1,000 follows in case of structurally complicated ore deposits. Underground geological mapping of ore deposits is usually done on the scales of 1 : 500, 1 : 200 and 1 : 100.

With regard to geological survey and prospecting of mineral deposits, the Ministry of Geology is guided by the Five Year Plans, on the basis of which annual work programme is chalked out. This ensures exploration of minerals to the fullest extent by successive Five Year Plans. The Ministry further revises the data on mineral resources of the Union every year. Geophysical explorations are very common in the U.S.S.R., and magnetic surveys are undertaken for the prospecting of ore as well as for geological mapping. Aerial mapping is being increasingly used in the survey of natural resources, and airborne surveys have been successfully employed for geological mapping and discovery of mineral deposits.

In the day to day work of any mine, geological work is considered very important, and very often the chief geologist of a mine works as a deputy director of that enterprise. The individual mines have their own team of geologists for large scale mapping, systematic sampling, assessment of reserves according to various categories, and mineralogical and petrological studies. Prospecting operations do not cease with the opening up of a particular mine, as ore reserves are revised annually, detailed revisions being done every four months.

The programme of mineral prospecting and exploration in the U.S.S.R. is universally kept ahead of the industrial development programme. As for instance, if any enhanced output of steel each year is contemplated, the additional quantity of various raw materials necessary is determined in advance, and the proportionate increase in annual output of iron-ore, limestone, coal and manganese-ore from certain mines is fixed up for maintaining the production target. According to Soviet practice, a coal mine must have a reserve of 10 million tons to yield an annual output of 300,000 tons, 50 million tons to yield 900,000 tons a year and 80 million tons to yield 1·2 million tons a year.

The ore reserves are grouped under 5 categories (A_1, A_2, B, C_1 and C_2), the higher category reserves being evaluated from very detailed prospecting and are ready for immediate winning. The low category reserves are based on scattered drilling or mere geological indications and are used for long-range preliminary planning.

Several Geological Expedition Parties belonging to various Territorial Departments work in many regions of the U.S.S.R. The workers of the Expedition Parties are provided with all modern amenities including hospital facilities, communications and supply, and a fleet of transport is also maintained. The organization of the Shing-Magian Geological Expedition Party is headed by a director, assisted by a chief engineer and a chief geologist. The Party has 18 senior geologists and 50 junior technicians, the other workers totalling about 1,000. About 5,000 meters of tunnelling and 6,000 meters of drilling are being completed annually. Mapping on a scale 1 : 10,000 covering 150 square kilometers was done within 5 years. The party is in charge of prospecting for antimony-mercury deposit in a mountainous country where large sums of money were spent for constructing roads, houses, laboratories, workshops and power stations, the annual expenditure incurred for the prospecting amounting to some 25 million Roubles.

A group of important mines in a region is generally worked by the so-called special Trusts or Combines. As for instance, the Chiatura manganese deposit in Caucasus, the largest of its kind in the U.S.S.R., is worked by the Chiatura Manganese Trust of the Ministry of Ferrous Metallurgy. This operates several mines and nine beneficiation plants.

The Tyrnyauz tungsten and molybdenum mine in Caucasus is worked by the Combine of that name and also operates the beneficiation plant and other subsidiary installations. The Combine works under the Ministry of Ferrous Metallurgy. The tenor of ore is the lowest worked anywhere in the world, and the working of this deposit signifies that they are determined to work even the exceedingly poor grade ores in the U.S.S.R. which may not be considered economical to work in other parts of the world.

When a particular deposit has been proved by the Ministry of Geology and Conservation of Mineral Resources, it is handed over to the Ministry concerned for development and mining. As for instance, if a deposit of copper-ore is proved by prospecting by the Ministry of Geology, it will be subsequently worked by the Non-ferrous Ministry, who will make necessary arrangements for communications, road construction, building houses, mining, ore-dressing, etc.

The Ministry of Coal is responsible primarily for planning, organization and coal mining, and is also connected with mines design, coal preparation, research and manufacture of mining machinery and equipment. Matters affecting supply, distribution, marketing and processing are dealt with by other Ministries. The designing and manufacture of machinery and mining equipment are done through various research organizations and precede the needs of the coal mining industry.

The exploration for oil is the concern of the Ministry of Oil. The Ministry has six branches, *i.e.*, Oil Refineries, Construction, General Organization and Technical Training, Land Oil Exploration, Off-shore Oil Exploration, and Equipment, each in charge of a Deputy Minister. Drilling for oil in the shallow Caspian Sea began since World War II, and an inspection of these oil wells bears testimony to the competent planning and geological diagnosis of the Soviet experts.

United Kingdom.—Controlled by the Department of Scientific and Industrial Research, the Geological Survey has 90 geologists although about 120 geologists are actually needed. There is a Museum of Practical Geology attached to the Survey. The principal Departments of the Survey are Palaeontological, Petrographical, Chemical and Spectrographic, Water, Geophysical, and Atomic Energy. Geological mapping is carried on a scale of six inches to one mile map, covering 270 square miles annually by primary survey and 270 square miles annually by revision survey. An area of 25,000 square miles is yet to be covered in Great Britain on six-inch scale for the first time. Prospecting for minerals and problems connected to their utilization are the concern of private enterprises and technical institutions although the Survey also performs some work.

The Colonial Geological Survey (London) was founded in 1946 with a view to co-ordinate the geological surveys in the British Colonies. It also plans and assists geological mapping, soil surveys, mineral surveys, aerial surveys and geophysical surveys for the Colonial Geological Surveys numbering twenty-one. The Mineral Laboratories of the Mineral Resources Division of the Colonial Geological Survey are of particular help to those overseas Colonial Surveys not having their own research or technical services. The British Colonial Welfare Fund is available for financial assistance to the Colonial Geological Survey. Headed by a Director, who also functions as an Adviser to the British Government, the Survey has 25 senior scientists and a complement of technicians. The Survey maintains close liaison with the Geological Survey of Great Britain.

East Germany.—A State Geological Committee in Berlin, with a network of regional bureaus, controls all geological work in East Germany. The Committee has two administrative branches. The geology branch is responsible for geological surveys, mineral investigations, soil surveys and ground water investigations. The exploitation technique branch conducts geophysical surveys and drilling.

West Germany.—There is no central Geological Survey of the Federal Republic of West Germany. Six out of nine Federal States of the Republic have independent Geological Surveys whereas the rest have a joint Survey. The Hanover Geological Survey is the most important organization in West Germany with up-to-date laboratories and highly trained technical personnel. The Department has 108 scientists (geologists, geophysicists, soil-scientists, geochemists, etc.). Geological mapping is generally done on a scale of 1:25,000, and in case of detailed work mapping is done on 1:10,000 and 1:5,000 maps. Auger holes and sinking of trial pits and drill holes are done to clarify problems. Geological maps on a scale of 1:100,000 are being published, each map having a corresponding published memoir. The publication of geological maps on a scale of 1:25,000, hitherto done by the former Prussian Geological Survey, has now been discontinued on financial grounds. Usually mapping of soils is done on 1:25,000 scale, thus showing a uniformity with the geological maps, but maps are printed on 1:100,000 scale. Detailed soil mapping on a scale of 1:5,000 is done in important agricultural areas. In addition, hydrogeological maps, deposit maps and maps showing tectonical structures are also prepared. The following are the principal departments of the Hanover Geological Survey: geological mapping and scientific work, mineral deposits excluding oil and gas, oil and gas, hydrogeology, engineering geology, soil science, mineralogy, petrology and geochemistry, geophysics and palaeontology. The Survey offers a few months' practical training to students of geology and geophysics every year.

Being a most thoroughly exploited country in the fields of mining, industry, agriculture and forest wealth, the present emphasis is not on a mere geological basis but on specialization and adoption of modern methods and techniques. Among the present day activities of the Hanover Geological Survey particular mention may be made of the prospecting for oil and gas and coal. Exploration for oil in West Germany was largely controlled by the Hanover Geological Survey. Expenditure for geophysical prospecting by the oil industry at 6-7 million Marks in 1950 rose to 18 million Marks in 1953. Extensive geophysical measurements with gravimeter, torsion balance and seismic equipment gave information regarding the depth, dip and faults of the Tertiary base in coalfields. Thousands of bore-holes were drilled and measured by "Schlumberger method" with a view to obtain a knowledge of the strata and the coal seams. In the Ruhr coal basin, the reflection seismic method solved various geotectonic problems.

France.—There is no organization in France akin to the Geological Surveys of other countries, and the responsibility of geological mapping rests upon the "Directeur du Service de la Carte Géologique de France". He determines the priority of the area to be geologically mapped and requests a geologist in the State who might be available for the purpose. University workers may be thus associated with such work. The cost is borne by the Government. The geological surveying and prospecting of mineral deposits in France are now-a-days carried out through the following Government subsidized bodies :—

(1) Geological, Geophysical and Mining Research Bureau (B.R.G.G.M.).
(2) Geology and Coal Deposit Service of the French Coal Mines.
(3) French Petroleum Institute.
(4) Atomic Energy Commission.

Established in 1953, the B.R.G.G.M. is controlled by a Board of Directors, under the supervision of the Ministry of Industry and Commerce. It undertakes on behalf of individuals, mining companies and Government, geophysical prospecting, geochemical prospecting and aerial surveying, in co-operation with other organizations including universities and mining schools. The service has a documentation section which offers information to the public, sometimes in the form of publications, maintains technical and scientific research laboratories, and has a mining and prospecting section. The prospecting section is fully equipped with drilling and geophysical instruments and is now working for ground water, coal, tungsten, columbite, copper, lead-zinc and uranium ores in several parts of France, and the recent finds of iron-ore in Bordeaux and Jura, oil at Briod (Jura) and pitchblende in the Massif Central, speak of achievement. The Bureau exchanges information with individuals, mining enterprises and private consulting organizations in a friendly spirit without going into competition. The Bureau can receive a share in the profits arising from the working of mines developed as a result of prospecting and checks on the use of funds made available to organizations receiving its financial help. In addition to the usual technical personnel (executives), the Bureau maintains a register of Associates from the industry or learned societies or Universities for consultation work.

The Geology and Coal Deposit Service of the French Coal Mines is operating at present in the coal basins of Nord and Pas-de-Calais, Lorraine, Loire and Garonne. The Geological Services of the Coal Basins deal with problems for large coal basins. "The Centre d'études et de recherches des Charbonnages de France", with a chain of laboratories, is an important research organization dealing with coal.

The Petroleum Research Bureau and the French Petroleum Institute are particularly concerned with oilfield geology, prospecting, research, etc.

Although in France there are several independent organizations performing identical or allied tasks, the geologists, geophysicists and other workers of the several services meet very often to co-ordinate their work. Prospecting for minerals is also undertaken by private companies.

North Africa.—The Director of the Geological Survey of Algeria is also designated as the "Ingénieur Général des Mines," but in actual practice the Geological Survey and the Mining Department are independent organizations. The "Bureau de Recherches Minières de l'Algérie" (B.R.M.A.) is a separate organization carrying out prospecting and utilization of minerals. Geologists specializing in hydro-geology are also attached to the "Service de la Colonisation and de l'Hydraulique" in Algeria. The Society of Electrical Prospecting at Algiers undertakes a number of geophysical surveys in Algeria and Morocco.

In Tunisia, the Geological Survey and the Mining Department are also separate bodies and are linked to the Directorate of Public Works Department. The "Société N.A. des Pétroles" and the "Compagnie des Pétroles de Tunis" are two separate organizations carrying out oil prospecting in the country.

The published geological maps of Algeria and Tunisia are generally on a scale of 1:200,000, the field surveys being usually carried out on topo-sheets on a scale of 1:50,000. It is said that modern topo-sheets on a scale of 1:50,000 are available for about a quarter of the area of these two countries, and that nearly one tenth of their extent has been geologically mapped on such maps. A number of geologists from the French Universities carry out geological mapping in parts of Algeria and Tunisia in collaboration with the permanent official geologists of the respective States.

Japan.—The Geological Survey of Japan was attached to the Ministry of Munitions during World War II, when sheet mapping was discontinued. The Survey maintains a technical staff of 270. The principal Departments are as follows: Geological (Mapping, Compilation & Engineering Geology Sections), Mineral Deposits (Metal, Non-metal and Ore Research Sections), Fuel (Coal and Oil & Gas Sections), Geophysical (Exploration & Research Sections) and Technical (Topography & Boring Sections). In 1946, the Survey shifted its headquarters to the present premises in Kanagawa Prefecture. There is a small city office at Tokyo. In addition, there is the Hokkaido branch office at Sapporo, and small circle offices at Sendai, Nagoya, Osaka, Hiroshima, Shikoku and Fukuoka.

In recent years the Survey's attention has been diverted to sheet mapping and long-term systematic mineral investigations. The recent advances include compilation of geological maps on the scale of 1:500,000 on the basis of new data. Published sheet maps, on the scale of 1:75,000, cover about one fourth of the entire area of Japan, excluding Hokkaido. Sheet mapping on the scale of 1:75,000 was commenced in 1947, and before 1952, 95 sheets were mapped, out of which 78 sheets are published. Mapping on the scale of 1:50,000 began in 1950, and it is proposed to adopt this scale in Hokkaido region also. In 1950 it was planned to publish the geological maps of Japan on the scale of 1:500,000, in 14 sheets, and already three sheets are published.

Established in 1952, as a result of amalgamation of the Fuel Research Institute and the Mining Technical Research Institute, the Government Resources Research Institute in Tokyo is mainly connected with problems affecting conservation, development and utilization of the mineral resources of Japan. The Institute employs 392 persons.

In Japan, geological researches are undertaken not only by the Government Departments and Universities, but also by several mining companies, who follow up-to-date methods of geological exploration. The Mitsubishi Metal Mining Co., Ltd., the Mitsui Mining and Smelting Co., Ltd., and the Nippon Mining Co., Ltd., are the front-ranking firms of their kind in Japan and are pioneers of the nation's basic industry. They have their own teams of geologists, geophysicists, mining engineers and chemists, and are equipped with research laboratories.

IV. GEOLOGICAL SURVEY OF INDIA

Geological Mapping.—Mapping in India has been generally restricted to the peninsula and the Shillong plateau, and only small portions of the high mountainous areas have been geologically mapped. The geological mapping since the last half a century has been in progress on the one inch to one mile maps (1:63,000). At present less than 20% of the country (263,000 square miles) has been covered on that scale, the area of the country being some 1,268,000 square miles. Although detailed mapping in the alluvial and deltaic regions (470,000 square miles) is not essential, these will have to be covered for ascertaining the ground water possibilities, clay resources, etc., and to locate any possible hidden structures for oil and gas. The Deccan traps (200,000 square miles) have not been mapped in great detail as yet ; mapping of the flows and dykes, which, apart from its scientific interest, may throw light on the ground water resources of the barren lavas.

The area that can be mapped in a field season depends on the terrain, the geological and structural complication of the area, the scale of the map and the nature of details to be shown. A geologist, on an average, can map about 250-350 square miles each field season working on one inch maps. Large areas of Saurashtra, Madhya Pradesh, Orissa, Assam, etc., have no modern one inch maps. The completion of mapping on one inch scale, mostly to be undertaken in inaccessible and mountainous terrains, will need a very large complement of geologists, exclusively employed for this work over several decades. At present annually about 8,000 to 12,000 square miles are being mapped on the one inch scale in this country. This fundamental mapping programme is a long-range one, which, however, will not cease with the completion of one inch maps of the Union.

Besides, revision of earlier mapping and detailed mapping of mineralized zones (Daribo, Khetri, Zawar, Kolar, Singhbhum, etc.), by plane-table and telescopic Alidade, and partly on aerial photographs, will have to be continued. Some large scale mapping has been done in parts of the coalfields and in certain areas, comprising 3,700 square miles mapped on 2″ to 1 mile (1 : 32,000) and 3,000 square miles on 4″ to 1 mile (1 : 16,000). With the development of the country's resources and better communications and transport facilities, the demand for large scale mapping is bound to increase for structural mapping, mineral development, assessment of ground water, engineering studies, etc. We have yet to prepare "drift maps", *i.e.*, mapping of alluvial and soil covered areas where a fair amount of geological data could be shown.

Now-a-days aerial surveying, aided by some ground control, can prepare topographical maps in a short period, and the aerial photographs are themselves utilized for structural information, preparation of geological maps, evaluation of oil possibilities, etc. Aerial maps are prepared by the Indian Air Force and private firms on contract for the Survey of India. Aerial photographs of certain areas only are available, and more areas are to be covered as quickly as possible, as otherwise many important geological works cannot be commenced. The Survey of India is saddled with demands from various quarters in connection with river valley projects, town planning, etc., and Government might consider to entrust the work to private concerns for speedy aerial mapping.

Status of Survey before World War II.—The Geological Survey was primarily engaged in the preparation of geological map of the country on the standard one inch to a mile scale which is the basis of all geological work including appraisal of the mineral deposits. Prior to World War II, over half a century, the number of officers was between 25 and 40, the budget allotment varying from 6 to 7 *lakhs* of Rupees only. In 1939, the Geological Survey possessed a technical staff of 30 consequent upon retrenchment.

Sir L. L. Fermor in 1922, in his Presidential Address to the Mining & Geological Institute, referred to the role of geology in the industrial progress of a country and emphasized upon the value of geological mapping. In his Presidential Address at the Indian Science Congress in 1933, he again stressed upon the necessity for a civilized country of maintaining an efficient Geological Department, and prophesied that re-expansion of the

Geological Survey of India will eventually be a vital necessity. The Survey then due to the then drastic retrenchment consisted of only 18 geologists for the whole of India and six for Burma.

Dr. A. M. Heron, in his Presidential Address to the Mining & Geological Institute in 1938, narrated the work and scope of the Geological Survey, then consisting of 26 officers, and pointed out that India has one geologist for every 72,000 square miles, Great Britain one for 1,600 and Russia one for 760 square miles. He pointed out the necessity "to restore the sadly retrenched Geological Survey of India at least to the scale laid down as desirable of attainment before the slump of 1929".

World War II Period.—The loss of Burma and Malaya in World War II accentuated the need for further search for minerals and location for airfields, roads, water supplies, construction materials, etc., and led to some recruitment to the Survey and the creation of the Utilization Branch which was abolished at the close of the war. Till then the Geological Survey was chiefly concerned with a general appraisal of the mineral deposits, and the task of the private lessees was to assess their actual potentialities by detailed prospecting. The exigencies of war necessitated the undertaking by the Geological Survey of detailed prospecting in several areas, exploratory mining (lead-zinc ore) and actual mining (sulphur, mica, wolfram, beryl, etc.) in case of strategic minerals in short supply. The strength of officers in 1944 rose to 65.

First Five Year Plan.—In 1945, the Government decided to expand the Geological Survey. The Five Year Plan prepared in 1946 envisaged reorganization and expansion of the Geological Survey and outlined a plan of work. The Survey in 1947 possessed 215 technical personnel, the number in 1954 increasing to 442, inclusive of 214 geologists, 41 geophysicists, 31 chemists and other technical personnel.

In 1945, several specialist sections (Engineering Geology Section, Ground Water Section, Geophysical Section, Drilling Section and Exploratory Mining Section) were set up and the number of Field Circles increased to six, and new Circle Offices at Bombay, Rajkot, Nagpur, Lucknow and Puri were created. During the period of five years ending in 1951, large areas were mapped on a scale of one inch to one mile (20,000 square miles in Madras) and a number of economic investigations and engineering geology and ground water investigations were carried out, in addition to work of the Technical and Chemical Sections at headquarters. Progress included setting up of a workshop, building up several instruments and obtaining some geophysical equipment from abroad.

Dr. W. D. West, in his Presidential Address to the Mining & Geological Institute in 1949, reviewed the actual and prospective work of the Geological Survey and stated that 'it needed the impact of two world wars to convince those in authority that the industrial progress of the country was largely dependent on the development of its mineral wealth, and that in turn was dependent on the work of geologists".

Second Five Year Plan.—The main objectives among others are (1) procurement of 40 drills for quick appraisal of deposits, large number of vehicles for field and setting up of three regional workshops, (2) absorption of personnel for Exploratory Tube Well Project (Indo-American Technical Co-operation Programme No. 12) in the normal cadre of the Geological Survey with a view to conducting detailed ground water surveys in the country, (3) creation of a Foreign Geology Division to assist the neighbouring countries of Afghanistan, Nepal, Burma, Indonesia, etc., and (4) expansion of the Geological Survey, the target of officers being 782.

The present cadre comprises 321 officers with an estimated budget allotment of 90 *lakhs* of Rupees. The Circle offices are now located at Madras, Hyderabad (two), Bombay and Lucknow. The capital expenditure for the equipment (geophysical, chemical laboratory, drawing office, vehicles, tents, survey instruments, drilling, etc.) for the first three years is earmarked at 160 *lakhs* of Rupees. The total budget for implementation of the second Five Year Plan is 500 *lakhs* of Rupees, and in addition the expenditure continuing from the first Five Year Plan will have to be borne.

Provision has been made for 3 self-sufficient Regional Offices with workshops, laboratories, libraries, museums, etc., at Calcutta (Eastern Zone) and in two centres in Northern and Southern Zones, each having some Field Circles, and 3 Specialized Divisions at Calcutta, *i.e.*, Economic Geology Division, Geophysical Prospecting Division and Engineering Geology and Ground Water Division. The disposition of the Circle Offices with respect to the Regional Offices will be as follows :—

Eastern Zone (Calcutta) ...	(1) Bihar, (2) Orissa, Bengal, Andaman and Nicobar Islands, (3) Assam, Tripura and Manipur, and (4) Central Himalayas.
Northern Zone	(1) Jammu and Kashmir, (2) Punjab, Pepsu and Himachal Pradesh, (3) Rajasthan and Ajmer, (4) Uttar Pradesh including U.P. Himalayas, and (5) Madhya Bharat, Vindhya Pradesh and Bhopal.
Southern Zone	(1) Bombay, Kutch and Saurashtra, (2) Madhya Pradesh, (3) Hyderabad and Andhra, and (4) Madras, Mysore, Travancore-Cochin and Coorg.

The programme of work comprises the items decided by all State Governments and other organizations, and those decided at the Mineral Conferences of 1954 and 1955. Some items would go beyond the scope of the second Five Year Plan. Fresh suggestions would be also invited periodically from the State Governments and other organizations.

The second Five Year Plan envisages intensive exploration for coal, copper, lead, zinc, manganese, chromite, gypsum, magnesite, etc. The maintenance of a properly equipped drilling section with trained personnel is essential towards that end. Surveys for locating coalfields will be made in Vindhya Pradesh, Madhya Pradesh, Uttar Pradesh, etc. Surveys and drilling explorations for oil, however, will be undertaken by the Oil and Natural Gas Commission.

V. GOVERNMENT AGENCIES AND MINERAL DEVELOPMENT

Existing Organizations.—The National Mineral Policy Conference in 1947 stressed upon the necessity for intensive mineral development with a view to ensuring increased output, conservation and utilization of minerals, and as a result the enactment of Mines and Minerals Act (Regulation and Development Act of 1948) followed with a view to adopting a uniform policy in the matter of grants of mining concessions. This is being replaced by a new Act (1956) to be approved by Parliament.

The Indian Bureau of Mines was set up in 1948 to ensure proper mineral development in the country, and the Geological Survey began to expand. The Department of Atomic Energy Commission has been set up to search for atomic energy minerals and to extract atomic energy for power production.

The setting up in recent years of the Fuel Research Institute, the National Metallurgical Laboratory and the Central Glass and Ceramic Research Institute, all linked to the country's mineral development projects, speaks of the National Government's endeavour to provide facilities for fundamental and applied research on scientific lines. A Technical Coordination Committee was set up in 1952, with a view to co-ordinating the work of the three National Laboratories with that of the Geological Survey and the Bureau of Mines.

Constituted in 1953, the All India Mineral Advisory Board advises the Government in various aspects of mineral industry and development. The setting up of Zonal Advisory Boards in Ajmer, Calcutta, Nagpur and Bangalore, is currently under way. A Mineral Transport Advisory Committee is being constituted.

The Planning Commission, in the first and second Five Year Plans, emphasized the urgent need for the proper appraisal of mineral resources, mineral exploitation and utilization of minerals, and has recommended further strengthening of the Geological Survey, the Bureau of Mines, and the National Laboratories directly concerned with the mineral development.

In recent years considerable efforts have been made by Government agencies to evaluate the mineral resources of the country. The highlights of progress in the Geological Survey during the last decade was given by Mr. V. P. Sondhi in his Presidential Address to the Geology and Geography Section of the Indian Science Congress in 1955.

A New Oil and Natural Gas Commission was set up in 1956 with the Hon'ble Shri K. D. Malavya as Chairman, to search for oil in the country, and a sum of 30 *crores* of Rupees has been earmarked in the second Five Year Plan for this purpose. Assisted by Russian experts this Commission is shortly going to drill for oil in Jawalamukhi in the East Punjab. Mr. A. M. N. Ghosh, my learned predecessor in the Section of Geology and Geography, is a member of the Commission.

A Proposal for a Ministry of Geology & Conservation of Mineral Resources.—The wise use and conservation of our water and mineral resources will go a long way in the national economy, but this cannot be achieved over night. With balanced development of our resources, we should be able to advance our national prosperity, and the Geological Survey of India has to play an important role—a crucially important task in achieving this objective.

Judging from the growing importance of the Geological Survey of India and all phases of mining, mineral development and industries in the country, in the second Five Year Plan, it would be advisable to have a separate Ministry of Geology & Conservation of Mineral Resources as in the U.S.S.R. This Ministry should have administrative control of the Geological Survey, the Bureau of Mines, the Fuel Research Institute, the National Metallurgical Laboratory and the Central Glass and Ceramic Research Institute.

The Ministry of Geology & Conservation of Mineral Resources should be the highest body of State geological service—the basic organ for carrying out all geological work in the country. The specialists and senior officers of the various Departments should meet periodically under the Chairmanship of the Minister and decide upon the development policies, co-opting outside specialists as necessary.

The Ministry would control the training of personnel in the field of geology and mining, and set the target of the number of students to be trained annually and thus guarantee employment to all students after graduation.

The Ministry should have a Geological Commission—a central co-ordinating authority, and its functions would be as follows:—

(1) Checking up reserve calculations, determining the degree and reliability of the studies of mineral deposits and finding out whether the deposits are suitable for commercial exploitation.

(2) Guiding and controlling the proper exploitation of deposits, rate of exploitation of deposits and reducing the mining losses.

(3) Controlling systematic production and utilization of minerals ensuring that all components of mixed ores are utilized, and making recommendations for national mineral policies.

(4) Planning of the programmes of the Geological Survey and the Bureau of Mines, and checking priorities on a national basis. In our annual programme we incorporate a chain of items mostly concerning a long-term programme, some of which would need several years to finalize. Continued pressure from influential individuals and State Governments often forces us to include investigations of unimportant mineral deposits and thus hinders a set programme of work.

The Ministry would naturally help the growth of mineral industry in the private sector and co-ordinate their work. In the French Union the setting up of new State sponsored organizations called Mining Bureaus has rendered it possible for the State to participate in mineral development. The structure and mode of operation of these Bureaus are identical to those of the private enterprises. Experience has proved that these Bureaus have a marked influence on the development of mining research and mining, and help to sustain private capital investment in a field where risks are great and profit making uncertain. We could profitably emulate the French example in the setting up of such Mining Bureaus with advantage.

The Ministry might also endeavour to make the public increasingly mineral minded, taking advantage of any agencies capable of assisting in this task, by publication of popular book-lets for the laymen, exhibition of minerals, etc. The Geological Survey has already proposed a scheme in this connection.

A Proposal for a Directorate General of Geology.—As the functions of the Geological Survey and the Bureau of Mines are not clearly defined, some overlapping or duplication of work is bound to occur. The Geological Survey should in future be associated in large measure with the assessment of mineral deposits by drilling to check its own geophysical and geochemical work. The development of mines and minerals should be assigned to the Bureau of Mines, which should supplement the work of the Geological Survey and also deal with mineral conservation, mineral statistics, safety of mines and mining research.

It is my firm belief that the Geological Survey and the Bureau of Mines should be merged under a Directorate General of Geology with headquarters in New Delhi. This will not only avoid unnecessary duplication of work, but will also yield quicker results.

The assessment of various mineral deposits in India is by no means complete and is naturally a slow process, dependent on the availability of more trained personnel and equipment. No immediate spectacular results are visualized and some disappointments might also result. Discoveries of new mineral deposits can be anticipated only after years of painstaking field and laboratory investigations. However, the available data regarding location, reserves and grades of India's mineral resources are adequate enough for formulating national policies for mineral exploitation and planning of industries based on mineral resources.

The steady rise of value of Indian mineral production from 22 *crores* of Rupees in 1939 to over 113 *crores* in 1953 is significant, and the future mineral industry in years to come is bound to increase considerably in view of our future demands, based on new mineral concession rules, incentives on right lines, systematic appraisal of minerals, mineral conservation, proper utilization of minerals, cheap electricity, etc. With this object in view, the Geological Survey and the Bureau of Mines should work in a greater unison under a common Director General, in the common endeavour to secure the maximum progress of the mineral industry and the balanced economy of the country.

The target of 782 officers in the second Five Year Plan seems very appropriate judging from the demands on the Geological Survey. The implementation of the Industrial Policy Resolution of 1956, in the domain of mineral development, warrants strengthening of the Geological Survey and procurement of adequate drilling and geophysical equipment at an early date The Indian Bureau of Mines is being strengthened, and a sum of one *crore* of Rupees has been earmarked in the second Five Year Plan.

Training of Personnel.—The shortage of technical personnel is at present an obstacle to the growth of mineral industry. There are about 800 geologists in the country, inclusive of professional geologists and those employed in various institutions, Government Departments, Universities, etc. Post-war planning and development programme consequent upon nation building projects sponsored by the State Governments and the Central Government, further accentuated the demand for large number of geologists in the country.

There are about 1,000 mining engineers in India. A large number of mining engineers, drillers and supervisory staff (foremen, overseers, surveyors, technicians, etc.) would be required for the growing needs of the mineral industry as envisaged in the second Five Year Plan.

The strengthening of the Geological Survey and the Bureau of Mines, the setting up of the Oil and Natural Gas Commission, and the country's need for increasing mineral development, will require increasing technical personnel in the field of geological mapping, engineering geology, geological and geophysical prospecting, mining, ore-dressing, mineral beneficiation, drilling, etc. Hitherto, the existing facilities available for geological and mining education have been defective. As such, the existing institutions should be expanded and their basic standard raised, and in addition new specialized courses like geophysics, oil geology, mineral dressing, drilling, etc., should be offered.

In India, 14 Universities provide geological education. The Indian School of Mines and Applied Geology offers diploma in Geology and Mining. Higher mining education is imparted at Banaras University. Geophysics is taught in two institutions. The present annual outturn of geologists and mining engineers is 150 and 55, respectively.

The number of geologists, geophysicists and mining engineers that would be required annually in various industries and research organizations including Geological Survey, Bureau of Mines and Oil and Natural Gas Commission should be determined so that the admission and training of specialists in various categories in the Universities and institutions could be controlled as in the U.S.S.R. and France. It has been decided to increase the present annual intake of 55 students to 110 in the Indian School of Mines and Applied Geology.

The Geological Survey Field Training Camp imparts field training to University graduates and new recruits. The new recruits are attached to senior officers before entrusting them with independent work. There is a proposal to offer field training facilities to the junior teaching staff of the Universities with the assistance of the Geological Survey, in collaboration with foreign specialists.

I would especially commend to your notice (1) the symposium on training of personnel for the mineral industry, and the recommendations of the implementation Committee, published in the *Transactions* of the Mining, Geological and Metallurgical Institute of India (1954), and (2) the Russian Experts' report on the training of geologists, geophysicists and mining engineers in India. The Russian Experts have stressed upon the necessity of a centralized co-ordinating agency for compiling model curriculum and supervising its implementation, adoption of specialized courses and a closer link between Universities and industries.

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SECTION OF BOTANY

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PRESIDENTIAL ADDRESS

AIR POLLUTION IN RELATION TO PLANT DISEASES

CONTENTS

I. Introduction ... ...
II. Industrial Gases ... ...
  Sulphur dioxide ... ...
  Fluorine ... ...
  Illuminating gas ... ...
  Ethylene ... ...
  Carbon monoxide ... ...
  Chlorine ... ...
  Hydrogen chloride ... ...
  Hydrogen sulphide ... ...
  Ammonia ... ...
  Nitric oxides ... ...
III. Factors influencing gas injury ... ...
IV. Smog ... ...
V. Invisible Injury ... ...
VI. Brick-kiln Fumes ... ...
VII. Diagnosis of air pollution injury to plants ... ...
VIII. Concluding Remarks ... ...
IX. Selected Bibliography ... ...

1. INTRODUCTION

The measure of a country's progress is the amount of coal consumed for industrial purpose. With the march of civilization industries spring up, chimneys raise their lofty heads and smoke, the visible exhalation of the combustion product of coal, pervades the atmosphere. It is specially true for bituminous coals which are rich in volatile products and produce the largest quantity of smoke when burnt. Coal, the essential constituents of which are carbon, hydrogen, oxygen, nitrogen and sulphur, variously combined, on complete combustion produces carbon dioxide, water vapour, free nitrogen and sulphur dioxide ; the last named is rapidly converted into sulphurous acid and sulphuric acid. In incomplete combustion depending upon the nature of the coal, the product is tar, phenols, illuminant gas, methane, ethane, carbon dioxide, carbon monoxide, nitrogen, gaseous hydrocarbons and unsaturated hydrobarbons. The coal smoke thus consists of "unconsumed distillation products in association with carbon, tarry matter together with dust and ash".

The effluents from industrial plants pollute the atmosphere ; the extent of this can only be realised when we consider that amount of coal annually consumed in India is about 36,000,000 metric tons. On the basis of 2 percent sulphur content of coal the total sulphur dioxide output in pure gas form is roughly 25,000,000,000 cu. ft. which represents a colossal figure considering that the gas at dilution of one part in a million can cause toxic effects in plants.

Air pollution is most serious in industrial towns. Usually diluted by wind current it spreads out without causing much visible harm either to plants or human beings, but under certain meteorological conditions, the effluent irritant gases unable to diffuse out, remain suspended in the atmosphere and cause enormous harm. Such was the condition in the Meuse Valley near Liege in Belgium in December 1930, when 64 persons died of respiratory disease. According to Roholin (1937) it was fluorine intoxication. Firket (1936) concluded that the noxious fumes were sulphur dioxide and sulphuric acid. In Donora (Pennsylvania) "stagnant meteorological conditions which confined smoke and waste fumes within the river valley caused 20 deaths and 100 hospital cases" (BYB 1949). "In winter of 1952 in the fog disaster of London some 4,000 people died within a fortnight ; all age groups were affected, but specially those over 45" (BYB 1954).

It is these and similar incidents that focus our attention to the gravity of air pollution as a danger to national health, and as the special committee set up by the British Government stated that "the air pollution in the scale we know today is a social and economic evil and must be combated with the same conviction as was applied 100 years ago in securing pure water" (HMSO 1954).

Besides, atmospheric pollution has a profound influence on the vegetation. Frings (1930) states that formerly flourishing forests on the north edge of the Ruhr are dying out as a result of fumes of industrial plants ; broad leaved trees affected by fumes even if not killed, become ready victim to fungi and insect pests. Similar smoke damages have also been recorded from other countries. In Canada, the damage to vegetation on account of fumes from the Smelter at Trail, started an international dispute, which brought the problem of sulphur dioxide injury to prominence (NRC 1939). Sulphur dioxide has been the source of litigations in other countries as well. Air pollution has serious effect on agriculture. It destroys growing crops, decreases their yield, damages vegetables, green house plants, flowers and nursery stocks. Middleton *et al* (1950) recorded the shifting of the location of operation by certain producers to areas free from gaseous effluence. The air pollution thus becomes a national problem.

The interest in air pollution follows the trend of industrialisation. The older works dealing with air pollution are from Europe. Most of the early literature originated there. It is comparatively recently that interest has gained momentum in U.S.A. Intensive researches are in progress in several centres on various aspects of air pollution and within a short period many important publications have appeared.

I propose to outline here today our present knowledge of air pollution in relation to plant diseases and shall briefly refer to certain aspects of these problems in India, which assume special significance in view of the increasing threat of air pollution from national programmes of industrial expansion. The problems arising from radioactive air pollution are beyond the scope of this survey and shall therefore be omitted from our present discourse.

Air pollutants are present in the atmosphere in three different phases : (1) gaseous phase, (2) aerosol phase which comprises an aerial dispersed system consisting of particles varying in diameter from 0·01-50 μ and

(3) particulate matter. Of these, the gas phase is more common and widely distributed and is the usual toxic phase. Aerosol phase appears during the periods of foggy weather when moisture drops dissolve the toxic gases. The particulate matter released in atmosphere, while by itself non-injurious, may help in the formation of aerosol (Middleton *et al* 1950).

The reaction of some susceptible species to minute quantities of gas is remarkable—for example, gladiolus var. Shirley Temple is sensitive to fluorine in one part per billion and at a lower concentration (0·1 ppb.) in longer exposure (Compton and Remmert cited by Thomas 1956). Similarly tomato plant is affected in a concentration of ethylene in one part in 100 million, and also shows extreme sensitivity to the presence of traces of phenoxic compounds (2,4-D groups) in the atmosphere (Zimmerman 1952). Plants showing this property are being utilised as test plants in order to detect the gases present in infinitesimal quantity in the atmosphere, which can hardly be analysed by any known physico-chemical method. The choice of a test plant will depend upon its specific reaction to a gas ; thus gladiolus for fluorine, tomato for ethylene. Test plants must necessarily be young, healthy and most vigorously growing. This ultra-sensitiveness of many plants to minute doses of gases and newly developed compounds may open up problems in agriculture.

The plant diseases caused by air pollutants are not systemic. The symptoms of injury are chlorosis and lesions which appear as spots and markings in the susceptible parts of plants. The susceptibility of the organs with reference to a particular gas is specific. In the case of sulphur dioxide, hydrofluoric acid, chlorine, indeed in most of the industrial gases, usually only the leaves are affected. The spotting and markings take place, and in severe cases of injury there is an abscission of the leaves. In susceptible varieties, at a long exposure stems are also affected. In the leaves it is the margin, tip and intercostal tissue which are more susceptible ; the veins are injured only at a late stage. In flowering condition the injury may extend to petals and to awns in grasses. It is only ammonia which produces discolouration of the general surface of the leaves.

The effects of illuminating gas and its components, ethylene, carbon monoxide and hydrocyanic acid are different. The injury in trees may appear in different forms in roots, shoots and leaves ; herbaceous plants can be defoliated, buds destroyed and actively growing shoots killed.

In evaluating the symptoms from the field studies, care should be taken to distinguish them from injury due to fungi, insects, nutritional disorders, drought and other physiogenic diseases. In fact it is suggested (Bredemann and Radeloff 1937) that final proof of gas injury is the chemical analysis to show the excess of the gas in the affected parts.

For convenience in discussion I shall now take up with you separately the plant disease problems arising from the effects of (*a*) industrial gases, (*b*) smog and (*c*) brick-kiln fumes.

II. INDUSTRIAL GASES

SULPHUR DIOXIDE

Various industrial gases have significant effects on plants. Sulphur dioxide is one of the commonest gaseous products of industrial plants and one of the most toxic. Its study dates back to 1850 (Stoeckhardt). Earliest detailed work is by Schroeder and Reuss (1883) who accurately described the injuries in conifers and deciduous trees. Since then the effect of sulphur dioxide on vegetation has been intensively investigated and several accounts are available of which publication of Canadian National Research Council (1939) is most comprehensive dealing exclusively with sulphur dioxide.

The characteristic symptoms of sulphur dioxide injury are well recognised. Broadly speaking the symptoms are chronic and acute. The chronic symptoms are found in leaves long exposed to gas in sublethal doses. The green colouration in interveinal portion changes to yellow. In acute symptoms the markings are marginal, intercostal and veinal. It starts as an watersoaked area, later assumes ivory colour or in some cases brown or brownish red. In cereals the leaf tips become red, then yellow, lastly white ; when flowering the awns are bleached. In barley, banded, mottled and kill-back types of symptoms have been distinguished (Katz *et al,* 1939).

A wide variety of species are affected by sulphur dioxide and indeed it is doubtful if there is any which is completely resistant to its effects. Species as also varieties within a species greatly vary in their susceptibility. Plants arranged in the decreasing order of susceptibility to sulphur dioxide injury, as given by O'Gara, are alfalfa, barley, sweet pea, bean, oat, clover and wheat followed by cauliflower, tomato, cabbage and grape ; the most resistant are apple buds and apple blossom (Thomas 1956, 9-8).

Among the plant parts, the leaf buds and developing leaves are most resistant and among leaves the middle-aged ones are most sensitive followed by older and then youngest leaves (Zimmerman 1949).

The susceptibility to sulphur dioxide increases over 40°F, below which the plants are resistant. The atmospheric sulphur dioxide absorbed by the soil does not injure the plants ; on the other hand it improves the plant growth in such soil where sulphur is not present in optimum condition.

Sulphur dioxide in a concentration one part per million may cause typical symptoms in leaves when fumigated for a few hours. 0·04 ppm. is the minimum concentration which alfalfa leaves are affected in short exposure (Zimmerman 1949).

The toxic effect of sulphur dioxide on mango fruit has been investigated by Ranjan and Jha (1940), Sen *et al* (1943), Das-Gupta *et al* (1941), and Verma (1952). The objective in all these cases was mainly confined to the production of 'nercosis' or 'black-tip' disease in mango fruit, and does not refer to the effect on other parts of plants. Sen *et al* exposed mango fruits on trees confined in glass jars to 0·5, 1·0, 2.5, 10.0 and 100 percent concentrations of sulphur dioxide for varying period. Exposure lasted 1-10 minutes for 100 percent and 1 to 3 hours for other concentrations ; some received intermittant treatment with 0·5 percent of gas. Das-Gupta *et al* exposed Safeda mangoes to very low concentrations of sulphur dioxide in a glass chamber specially designed for the purpose. The problem was reinvestigated by Verma with improved technique for administering minute doses in continuous current with variously designed apparatus by Datta (1944), both for mangoes on trees and for plucked mangoes. Sulphur dioxide was found to produce lesions in concentration of 46 : 10,000 in 20 to 30 minutes depending upon the mango variety tested. The mangoes of the size of the pea were more sensitive than the mangoes of ½″ length. Sulphur dioxide produced brick-red lesions round the lenticels on general surface of the fruit. Heavy doses produced large brown patches through the coalescence of these lesions. At lower concentrations, the number and size of lesions per unit area were roughly proportional to the concentrations of sulphur dioxide administered in a given time. At still lower concentration, 4 : 10,000, fruits showed chlorosis and shrinkage of tissues at the tip. The histopathological study showed that in the affected region epidermal cells lost chlorophyll, the starch grains became less in mesocarpic cells, cell walls were coloured brown, and light brown deposits appeared in cell cavities. The affected area was delimited by the production of cambium tissue which produced cells which were ultimately suberised (Das-Gupta and Verma 1941).

FLUORINE

Fluorine damage to vegetation, known for a long time near industrial plants, has in recent years gained much prominence as apart from causing foliage injury, it causes fluorisis of cattle and sheep feeding upon them. Fluorine in the atmosphere is present in the form of hydrogen fluoride, silicon tetrafluoride and fluosilicic acid.

Fluorine injury has been reported in the neighbourhood of aluminium, copper, iron, glass, brick, superphosphate and other chemical factories. Fluorine emitted by these factories is either directly absorbed by the plants or through the soil. The fluorine in air even in areas where gas injury is seen has an average less than 0·05 ppm., although leaves growing in the damaged area contained very high concentration of fluorine viz. 500 ppm. —1000 ppm. In soil fluorine is present in a larger concentration. Plants growing in soil rich in fluorine, have many times higher content of fluoride in their roots than in the leaves, but when fluorine is absorbed from the atmosphere, it is the leaves that contain a much higher concentration. In either case because of translocation the fluorine content of leaves is never inconsiderable.

Symptoms of injury caused by fluorine depend upon the susceptibility of host and in this respect there is a wide range of variation among the different species. Even there are intervarietal differences in susceptibility. In a given susceptible variety the symptoms vary with the concentration of gas employed. In very low fluorine concentration, one part per billion, on long exposure, gladiolus develops ivory-white or brown necrosis, the earlier symptoms being the water-soaked areas developing in the tip of the leaves. In higher concentration, one part per million, acute markings occur in the marginal and intervenial regions of the leaves, which are comparable to typical sulphur dioxide markings. In fact, sometimes they are indistinguishable in appearance.

In apricot and prunes the margin of the leaves first becomes yellow, then brown followed by necrosis of the tissues and the abscission of leaves (De Ong 1946 ; Miller *et al* 1948). In a heavily affected orchard about 50 percent of the injured leaves may be abscissed. Fluorine injury of fruits in which apical part is affected has been recorded by Neger (1919) for apple by Kotte (1929) for plum and Radeloff (1939) for pear. In corn the symptoms are somewhat different. A low concentration of fluoride produces a chronic mottled type of injury followed by slight collapse of the tissue. The injury spreads over an extensive area of leaf and is not confined to tips and margins only (Thomas 1956).

A wide range of species are affected by fluorine. Some of these are arranged in order of their susceptibility, viz. gladiolus, pine (young needles), azalea, Italian prune, corn, peach, grapes, iris, and most resistant are pine (old needles) followed by citrus, zinnia and rhododendron (Thomas 1956, 9-23).

Unlike sulphur dioxide injury there is a time lag between fumigation and the development of the disease which is due to the time taken for the translocation of fluoride from the seat of absorption to the tip and marginal regions where the fluoride accumulates. The absorption of fluoride from the soil and its translocation to the leaf and also its exhalation into external atmosphere as observed by Zimmerman and corroborated by air analysis are intimately connected with the accumulation and ultimate injury.

ILLUMINATING GAS

Illuminating gas when present in soil in a large quantity greatly disturbs the metabolism of plants inducing various kinds of abnormal tissue formations in stem and root (tubercle) and in some cases causing outright killing (Stone 1906, 1913 ; Doubt 1917 ; Harvey and Rose 1915).

On aerial exposure flower buds of carnation fail to open at a very low concentration of illuminating gas (1 ppm.) ; at a higher concentration actively growing rose shoots, bud shoots of caranation and flower buds of lilium were killed, and there were also stunting effects, defoliation of rose buds and rolling and curling of leaves (Wilcox 1911 ; Zimmerman *et al* 1930, 1931-a).

The illuminating gas injury of aerial organs is mainly due to ethylene. It has been shown that in rose plants the effect of the two are essentially similar, only ethylene produced injurious effect (epinasty) at a much lower concentration (1 : 3,000,000) against that of the illuminating gas (1 : 10,000). Ethylene constitutes 3 per cent of the total gas. The injury to roots, however, is due to hydrocyanic acid as shown by the loss of soil toxicity with disappearance of the acid (Hitchcock *et al* 1934).

ETHYLENE

Ethylene which has an important effect on plant metabolism, is also toxic at a relatively high concentration. The characteristic symptoms of ethylene injury are yellowing along veins from base to midrib followed by abscission, interference with elongation of shoots, the premature opening of flower buds and early fall of petals (Zimmerman *et al*. 1931-a). Contrary to the finding of Zimmerman, Shull (1930, 1931) reported loss of vigour in ethylene treated plants, notwithstanding the initiation of a large number of shoot primordia. The relation of temperature to disease development was found when no injury occurred below 50°C.

Ethylene stimulation induces the formation of intumescences under a wide range of biological conditions. The minimum concentration in which intumescence is formed is one part per hundred millions on a long exposure, but more readily when the concentration is increased to one part per million. Temperature exerts a marked influence on the number and size of intumescences ; the optimum temperature for their formation is 15°C and the maximum is 30°C. Part of the same individual tree, the humidity and light have no influence in the absence of oxygen nor in the presence of 25 percent or more carbon monoxide (Wallace 1926, 1927).

The toxic effect of ethylene on mango fruit has been investigated by Ranjan and Jha (1940), Sen *et al*. (1943) and Verma (1952). Sen using 1·0, 5·0, 25·0 per cent pure ethylene on mango fruit found that pure gas has no effect whereas dilute gas turns the skin of the fruit yellow and produces deep brown or black lesions under the skin, fruit becomes soft and drops out subsequently. Verma using the improved continuous current apparatus obtained results different from those of Sen and found that under laboratory conditions ethylene concentrations of 3 in hundred thousand to 5 in hundred thousand parts of air have no effect. At 1 in ten thousand, induced ripening and changed the green colour to yellow; heavier concentration induced lesions as well as ripening; and 12 parts in ten thousand rendered skin coat loose accompanied by formation of large brown patches on skin.

CARBON MONOXIDE

The toxic effect of carbon monoxide on plants was demonstrated by Richards and McDougal (1904). The effect at a higher concentration expressed itself in the retardation of stem elongation, differentiation of primary tissues and chlorophyll formation. There is the production of abnormally small leaves of normal shape, yellowing and their abscission. Formation of hypertrophied tissues in stem and root of most species has also been recorded (Knight and Crocker 1913; Zimmerman *et al.* 1933, 1933-a). Lower carbon monoxide concentrations evoked physiological responses, such as rooting, stimulation of older stem primordia, epinasty of leaves, growth vigour, loss of sensitiveness to external stimuli and behaved like an anaesthetic (Zimmerman 1935).

Das-Gupta *et al.* (Ann. Report 1941) and Sen *et al.* (1943) employed carbon monoxide in various concentrations to ascertain its toxic effect on mango fruit, with particular reference to the production of 'necrosis' or 'black-tip' disease of mango. The results obtained by both are essentially similar. Sen *et al.* exposed fruits of *Aman Dasheri* variety of mango for 72 hours at 1 percent, 5 percent and pure carbon monoxide and observed that in 1 per cent concentration fruits were completely unaffected, at 5 percent very slight paleness was visible, but no change thereafter, whereas in pure carbon monoxide skin became yellow and fruits remaining hard persisted on tree and showed retardation in growth.

CHLORINE

Injury due to chlorine is rare in nature although it is much more reactive than even sulphur dioxide. The characteristic symptoms are marginal and interveinal injury which starts as water-soaked areas, turning brown and in more severe attack followed by abscission. In sugarbeet the upper epidermis may be affected giving it 'silver-leaf' appearance. The symptoms resemble those of sulphur dioxide rather than hydrogen fluoride. Minimum dose for a very susceptible test plant was 0·46 ppm. (Thornton *et al.* 1940). The investigation of Zimmerman (1949) exposing chlorine to a wide range of species showed that at 0·46 ppm. buckwheat (*Fagopyrum esculentum*) is affected in 1 hour; at a higher concentration, 1·3 ppm., bean and radish take 30 minutes to show the symptoms and peach 3 hours at 0·56 ppm.

HYDROGEN CHLORIDE

Hydrogen chloride had been the cause of damage to vegetation when the gas produced as a by-product in Leblanc soda process was allowed to pass out in the atmosphere. Since the recovery of the gas was started it has ceased to be a problem (Thomas 1951). Hydrogen chloride is less toxic than sulphur dioxide. The lesions principally are marginal, interveinal or on tips of leaves. These are not distinguishable in appearance from sulphur dioxide injury (Thomas 1951).

HYDROGEN SULPHIDE

Toxicity of hydrogen sulphide is the least and effective dose is between 40-400 ppm. Typical symptoms are scorching of leaves, resulting in ultimate death. Youngest leaves are most sensitive while mature actively functioning leaves were uninjured, which is contrary to the action of other gases (Thornton *et al.* 1940). Most susceptible plants were cosmos, radish, tomato, cucumber, while most resistant species are coleus, peach, strawberry, apple and carnation (McCallan *et al.* 1936).

AMMONIA

Ammonia is less toxic than sulphur dioxide. Otto (1928) described ammonia injury to spruce in which needles turned pale green, then nearly white and finally red. The bark and wood of exposed side died out followed by the death of the tree. In tomato, sunflower and similar plants ammonia produces discolouration of the general surface of leaf "changing from green to cooked green finally brown upon drying". Concentration of 8·3 ppm. of ammonia seems to be threshold value for causing toxic effects in some plants (Thornton *et al.* 1940).

NITRIC OXIDES

Plants exposed to a weak concentration of nitrous gas under a bell jar for 15 minutes to 18 hours produced some lesions at longer exposures. Symptoms are marginal browning and brown spots on leaves (Christiani 1927). The blades of cereals and needle-tips of conifers showed bright yellow colour. Nitrogen oxides are important as reacting with atmospheric unsaturated hydrocarbons they may produce smog.

III. FACTORS INFLUENCING GAS INJURY

The injury of plants due to gas is directly proportional to the amount of gas absorbed. This absorption is the function of the general leaf surface or the stomata. Whether the absorption of sulphur dioxide is through general surface in which stomata plays no important role (Haselhoff and Lindau 1903) or the gas enters through the stomata (Janson 1937) or both (Verplancke 1927) was settled when it was demonstrated that absorption is controlled by stomatal aperture, a view which is now generally accepted (Thomas *et al.* 1935). By determining the physiological condition of the plant within the general condition of maturity, the environmental factors on the other hand influence the movement of the stomata and thereby the entry of the gas into the leaf.

The age of the plant subject to gas exposure thus plays a significant part in gas absorption. It is seen that usually the older plants which are most susceptible to gases and the youngest plant most resistant (Setterstrom *et al.* 1939) but there are also cases where young plants are more susceptible than the old (Widstoe 1903).

Again full grown and highly functional leaves are more susceptible than the old leaves and the young ones are more resistant when exposed to sulphur dioxide, hydrogen fluoride, chlorine and other gases except for hydrogen sulphide in which the youngest parts of the plants and leaves and rapidly elongating tissues are most susceptible (Hill *et al.* 1933 ; Setterstrom *et al.* 1939).

Among the environmental factors temperature plays a well-defined role in gas absorption. It shows particularly for sulphur dioxide, that plants growing below 40°F are most resistant (Swain 1923). There is an indication that above 100°F the plants may be more resistant (NRC 1939). Within this range there is no significant difference in absorption due to temperature variation. In mango necrosis the earlier phase of the development of fruit and the incidence of necrosis occur at a time when the atmospheric temperature in Lucknow is over 100°F and the main development of necrosis as well as the fruit takes place when temperature ranges between 105°F to 115°F.

The minor variations in soil moisture and humidity have no effect on the susceptibility of plants, but when the moisture content of the soil is reduced to the critical level of wilting, the resistance increases. The near-wilting condition decreases the turgidity of leaf cells effecting the closure of the stomata with consequent decrease in absorption. In mango necrosis the susceptible trees highly irrigated with water showed no discernible change in the number of diseased fruits (Das-Gupta *et al.* 1941-1951). Atmospheric humidity within a wide range has little effect on the absorption of gas.

Since stomata close in the dark checking the entry of the gases, plants grown in complete darkness are more resistant than those growing in light. It is for the same reason that an individual plant is more resistant at night than in the day and in cases where stomata do not close in the night, such as in potato and alfalfa, the resistance at day and night is the same. Plants grown in reduced light before fumigation are also more resistant.

The plants with deficient supply of nutrients proved to be more susceptible. In mango necrosis somewhat similar results have been obtained, not by manurial treatment, but by branch injection of Knop's nutrient solution. Intensive spray of diseased trees with borax showed that the disease advance and perhaps also incidence was greatly checked (Das-Gupta *et al.* 1940-1951).

IV. SMOG

Smog, a mixture of smoke and fog, appears in industrial cities where a large amount of organic and inorganic pollutants produced by the burning coal gas and other fuels pervade the atmosphere. Under certain meteorological conditions it may not have fog as its constituent, and then it is known as smog gas. The constituents of smog occurring in Los Angeles are sulphur dioxide, ammonia, oxides of nitrogen, sulphur trioxide, aldehydes, filterable oils, soluble chlorides, carbon, ozone, hydrogen sulphide, traces of minerals, organic peroxides, acrolein, fluorides, methyl chloride, formic acid, sodium chloride and gaseous hydrocarbons. Sulphur dioxide and fluorides are also present but in subtoxic concentration (Middleton *et al.* 1950).

The smog is usually present in the atmosphere to a greater or less degree, but when there is an accumulation and increased concentration of pollutants, the smog damage appears.

The symptoms of smog injury in plants are different from those characteristic of sulphur dioxide and fluorine injuries. The characteristic symptom due to gaseous component of smog (smog gas) is a glazed appearance on the undersurface of the affected leaves ; in some there is bleaching developing into light-tan necrotic area. The glazed appearance is due to the collapse of mesophyll cells and their replacement by air in the intercellular spaces. In severe attack scorching and necrotic spots appear involving entire leaf.

When smog is associated with heavy fog (smog fog) moisture is deposited on leaves as minute droplets which are somewhat acidic in character (acid aerosols). The deposits in contact with the leaf tissue produce leaf spots which advance progressively from upper surface to lower surface and ultimately develop into shot holes. No glazing or bleaching appears in these leaves. Similar injury is found to be produced by ozone (Haagen-Smit 1952a) which sometimes is a smog component.

As with other gases, the different species of plants show different degree of susceptibility to smog damage and some of them are named here in order of decreasing susceptibility. Endive, spinach, lettuce, barley, alfalfa. Most resistant is wheat followed by squash and rhubarb.

The nature of the smog agent was unknown till recently when the work of Haagen-Smit *et al.* (1952-a) and Koritz and Went (1953) appeared. Haagen-Smit (1952-a) while determining the compounds producing typical smog damage has shown that "the reaction product of ozone with unsaturated hydrocarbons produced typical smog damage on all the indicator plants. The damaging factor must, therefore, be attributed to the peroxides formed in the ozonization process". They were thus able to show that the vapours of some unsaturated hydrocarbons when combined with ozone or nitric oxide form a synthetic smog which causes plant injury identical to natural smog damage. Hydrocarbons which are normally non-toxic thus combined with another substance become very toxic. On the basis of this Koritz and Went (1953) prepared synthetic smog in the laboratory (1-*n*-hexene *plus* ozone) with a view to study the physiological action of synthetic smog on tomato plants.

Smog has been found to have retardation effect on growth of tomato plant (test plant) only when fumigated in light at midday or early afternoon. Fumigation in the dark or light following a 12-hour dark period or in the dark after 1½ hours of light had no smog effect. Koritz and Went (1953) also proved the presence of invisible injury due to synthetic smog.

Smog damage to plants, though not as extensive as that caused by irritant gases such as sulphur dioxide, fluorine and other industrial fumes, is nevertheless in several ways more important due to its effect on human health and of the invisible injury to plants caused by it.

V. INVISIBLE INJURY

Some workers consider that long exposure of sulphur dioxide at sublethal doses causes invisible injury to plants, in which the plant does not suffer damage externally, but there is a reduction in the growth and reproductivity due to the interference of the gas in the assimilatory process. The view gained prominence and was debated during the early phase of the work on sulphur dioxide (Schroeder and Reuss 1883; Sorauer and Raman 1899). It has been revived by Stoklasa (1923) supported by several workers (Haselhoff *et al.* 1932; Jansen 1936, 1937). No experimental evidence has, however, been put forward to substantiate the view. The experimental evidence put forward by Swain and Johnson (1936) showed that wheat plant grown in otherwise optimum condition, on long exposure to sulphur dioxide, failed to show any reduction in yield. This finding was substantiated by Katz *et al.* (NRC 1939) for alfalfa. The photosynthetic and respirational studies by Thomas and Hill (1937) proved that "yield is a linear function of the extent of leaf area destroyed", and no depression in assimilatory process occurs in the absence of visible damage. An extensive experimental study of alfalfa under different growth conditions exposed to sublethal concentrations of sulphur dioxide did not show any adverse effect (Setterstrom *et al.* 1938).

Recently, however, the question was reopened when Bleasdale (1952) working with a strain Aberystwyth 23 of *Lolium perenne* L. (rye grass) grown under controlled glass house conditions and exposed to polluted air of Manchester, found no trace of leaf damage, but "the treatment with purified air gave, with one exception, a dry weight considerably higher than treatment with polluted air". Koritz and Went (1953) investigating the physiological action of synthetic smog found a similar result on the growth of tomato plants. They demonstrated that synthetic smog may retard the yield of tomato plant without showing foliar markings or reduction in its photosynthetic tissue and stated that hidden damage or invisible injury as caused by smog may be widespread affecting many urban areas. It has been further suggested by Koritz and Went that it is very likely that 'Bleasdale effect' was due to some phytotoxic substances related to smog as found by them.

The present position, therefore, is that invisible injury is not caused by sulphur dioxide or most other similar gases, but it is caused by smog.

VI. BRICK-KILN FUMES

Brick-kiln fumes are the incomplete combustion product of coal at a comparatively low temperature, and to a certain extent mixed with the volatile substances present in the soil from which bricks are made. The fume constituents, although not fully worked out, comprise sulphur dioxide, ethylene, various hydrocarbons, and some tarry substance in unknown proportions. The fumes produce a disease of economic importance known as 'necrosis' of mango fruit (*Mangifera indica* L.), also designated as 'black-tip' because of the characteristic final symptom of the disease. The disease occurs near operating brick-kilns (Das-Gupta *et al.* 1939; Pal *et al.* 1937; Sen *et al.* 1941).

Necrosis invariably appears at the tip of the fruit; the first external symptom is aetiolation of the apical region followed by small greyish spots which coalesce to form a continuous necrotic area of dark brown colour. Due to the disintegration and collapse of the epicarp and mesocarp tissue, stone emerges and remains protruding beyond the healthy flesh giving the characteristic final phase of the necrosis. In recent years, a variation of typical necrosis called 'girdle necrosis' has been discovered by Rai (1952). In this, the focus of necrosis is usually in the sinus region and there is usually more than one focus; the final symptoms are indistinguishable from typical necrosis.

The internal symptom of necrosis is the presence of certain deposits in vessels and later on both in vessels and ducts. The deposits in the initial stages are fluid light-yellow, which passing from viscous deep yellow to semi-solid and solid brick-red types, ultimately become solid and dark brown in colour. The presence of deposits in the vessels is the first internal index of the disease (Das-Gupta *et al.* 1955).

The experimental fumigation with coal gas has produced typical necrosis in a number of fruits of a susceptible variety (Sen 1942-43). Similar investigations by Das-Gupta *et al* (1944, 1951) were only partially successful as number of mangoes developing necrosis was small. The disease was, however, successfully produced by injection of sterile extract from diseased tissue (Das-Gupta and Venna 1940). The fumigation of mangoes with the fume constituents, sulphur dioxide, ethylene and carbon monoxide separately, as stated elsewhere proved unsuccessful.

Isolation from the brick-kiln fumes of a certain crystalline substance which when injected into the mango fruit produces typical necrosis is of great interest (Das-Gupta *et al* 1950). The substance is as yet unidentified ; and its isolation in extremely small quantity makes it difficult to ascertain its effect in fruits without direct injection.

There was some indication that nutritional deficiency plays a part in the development of mango necrosis. When Knop's nutrient solution was applied to the tree with branch injection, in about 70 per cent of the fruits the earliest stages of the disease were checked. Spraying borax and boric acid solutions on fruits showing the early stage of necrosis checked the further advance of necrosis and the incidence was minimised (Das-Gupta 1950 Ann. Rep., Das-Gupta and Sen 1956). There is so far no further record from India of injury to vegetable and other crops due to brick-kiln fumes, though an intensive study using test plants is most likely to reveal cases of incipient or visible smoke injury, particularly in view of the fairly significant sulphur dioxide content (47 : 100,000 parts of air) of the orchards situated at a quarter mile distance from the fume source (Verma 1952). The vegetation near the industrial centres too should similarly reveal injuries effect and it deserves careful investigation.

VII. DIAGNOSIS OF AIR POLUTION INJURY TO PLANTS

From the foregoing observations it would be clear that in a large majority of cases, injury suffered by plants due to air pollutants is expressed in the form of foliar damage. In more acute conditions, the young shoot tips and developing buds may be affected and there are also records of fruit tip injury in apple (Neger 1919), plum (Kotte 1929), pears (Radeloff 1939) and mango (Das-Gupta and Verma 1939). Apart from this, in the case of smog, the plants suffer from invisible injury also. Precise diagnosis of air pollution injury to plants is, however, beset with many practical difficulties. Symptoms caused by gas exposure often simulate those resulting from other types of disorders arising from causes physiogenic (drought, frost, winter injury and nutritional unbalance, etc.) and pathogenic (viruses, bacteria and fungi). It is thus necessary to distinguish between them. This problem has been dealt with at some length by Massey (1952).

Symptoms caused by different gases vary, and a particular gas may evoke different symptoms depending upon the conditions of exposure and the species, or even variety, affected. Several workers have carefully investigated the symptoms caused by individual gases under field and experimentally controlled glass-house conditions, using a wide range of species of plants, including conifers, fruit trees, cereals, vegetable and forage crops, ornamental and green house plants, belonging to both monocot and dicot groups, and distinguished as herbaceous, woody and broad-leaved forms. The plants at different stages of maturity have been studied under exposure to very minute (0·01 ppb) to much higher concentrations of gases, and various conditions of light, temperature, nutrition, relative humidity and soil moisture. The symptom complex shown by a particular species has been worked out, making it possible to diagnose gas injury with a fair degree of accuracy. But even with this detailed knowledge of symptomatology it is difficult to confirm the diagnosis. This has been emphasized by Katz (NRC-1939) in the following words:

"Within a given smoke zone, however, there is usually formed a wide variety of makings which may be caused by other factors such as drought, frost, winter injury, insects, disease and various physiological disorders. Accurate diagnosis of the distribution and degree of injury is, therefore, a difficult matter unless some knowledge is available of the character and intensity of gas visitations, the meteorological conditions, the sulphur content of the affected plant, and the reaction of susceptible indicator plants. The careful investigator must, therefore, utilise as aids in the diagnosis and estimation of injury, such knowledge as may be available by a study of factors enumerated above".

Once the air pollution injury in a plant has been screened out from other disorders, the problem devolves itself to the specific identification of the pollutant responsible for it. As has already been mentioned earlier, the effluents from industrial sources contain a variety of pollutants including sulphur dioxide, fluorine, ethylene, hydrogen sulphide, carbon monoxide, chlorine, and other organic and inorganic substances, occurring in variable proportions. The composition of the effluents depends upon the nature of the coal or other fuels, and the nature of ore etc. employed in a particular industry. Sulphur dioxide content of the effluents increases when high-sulphur coal is used or during the roasting of sulphide ores. Fluorine compounds are commonly derived from impurities and are mostly found in the effluents from aluminium, copper, iron and superphosphate factories. The effluents of the various chemical industries have also different gas composition.

In diagnosing symptoms arising in a given smoke-pervaded region, the possible agency of several gases detected in the region is to be taken into account. For sulphur dioxide and fluorine, for example, Thomas *et al.* (1949) states that "the lesions due to hydrogen fluoride are somewhat similar in appearance to acute sulphur dioxide markings, but their location on the leaf is often different" ; the difficulties attended upon evaluating the markings, however, have been experienced and pointed out by several workers. Thus for both sulphur dioxide and hydrogen fluoride, diagnosis based on symptoms alone is not always possible (Johnson, *et al* 1950). The position with regard to minor gases, such as chlorine, hydrogen sulphide becomes even more difficult. It is yet to be found out whether several gases present in sublethal concentration are able to produce any disease symptoms.

The use of 'indicator' or 'test' plants is another method of detecting the atmospheric pollutants in a given smoke-pervaded region. The method is based on the differential reactions of different species and varieties of plants to the commonly occurring gases. The ultra-sensitiveness of various species has given an impetus to this work and intensive investigation is in progress in various laboratories abroad, in which the susceptible varieties grown under controlled condition in an atmosphere in which the desired gases can be introduced in infinitesimal doses. As a result of such investigations the various species of plants have been divided into three different groups, susceptible, intermediate and resistant, for each of the three important toxic agents, sulphur dioxide, fluorine and smog by Thomas (1956). Differential reaction of test plants sensitive to the various air pollutants can be employed to detect the specific injury causing substance in the atmosphere and it may even be possible to utilise this technique for making a fair surmise of the pollutant concentration present there.

Symptoms alone, however, are not very reliable guides to the diagnosis of the disease or the detection of the presence of pollutants in air. Symptomatological evidence of air pollution injury in plants needs corroboration by other more objective techniques.

The chemical analysis of diseased tissue as a method of demonstrating gas injury has been suggested by Bredemann and Radeloff (1937). For the confirmation of both sulphur dioxide and fluoride injury chemical analysis of affected tissues has been taken up. Its value for sulphur dioxide injury, however, is doubtful. The sulphur content of leaves of plants exposed to sulphur dioxide has been found to increase substantially (NRC 1939). But while there is a correlation between sulphur content of leaf and disease production in certain cases, there is evidence that the visitation of a high concentration of gas may produce disease symptoms, finally death, without increase in the sulphur content (Johnson *et al* 1950). On the contrary, as pointed out by Katz (NRC 1939), the accumulation of sulphur in leaves of plants exposed to sulphur dioxide atmosphere may reach values more than three or four times the normal content without showing external injury.

The fluoride content of the tissues affected by hydrogen fluoride has received considerable attention. The absorption of fluorine from the soil and atmosphere, its translocation to the leaf margins and tips from the root, as also from the seat of absorption of the leaves, its accumulation and final volatalization, are peculiarities not shown by other gases causing injury to plants. Johnson *et al* (1950) pointed out that "physical appearance is not enough to distinguish fluorine injury to plants ; the symptoms must be correlated to other facts, including an abnormally high fluorine content of the tissue".

Thus the result of the study of the fluorine content of air soil and the vegetation throws an interesting light on the problem of fluorine damage. Miller *et al* (1952) investigating the ponderosa pine blight where trees were injured by fluoride from an aluminium plant, found that whereas the area outside the influence of gas had needles containing 2-4 ppm of fluorine, within the affected area, the current year needles contained 129 ppm of fluoride and three year old needles as high as 462 ppm ; the fluoride concentration of air being 0·064 ppm.

The fluoride content of the air near a superphosphate plant was found to be 0-0·29 ppm (Largent 1949). Near an aluminium factory, fluoride content in the vegetation ranged from 5 to 1000 ppm. The concentration is variable since the accumulation of gas effluents from the factories and that from exhalation of leaves depends upon the velocity of wind. High fluoride content of tissue may not always reveal the disease symptoms. There is a great difference in the ability of a plant to absorb and tolerate fluorine. Concentrations as high as 5000 ppm have been observed in uninjured cotton leaves (Thomas 1951).

Chemical analysis, therefore, though it may confirm the findings from other methods, cannot be used as a sole criterion unless tolerance value of each plant is known ; this, then leads to the experimental production of the disease by suitable gas exposure.

Apart from chemical methods, physical techniques, though of limited value, have also been employed in the diagnosis of gas injury in plants. "Dorries (1932) has developed a method which although not specific for sulphur dioxide serves to detect injuries caused by acid gases. He believes that in case of acute injury, the acid gas acts directly on the chlorophyll, changing it into phaeophytin, through the splitting off of magnesium. The presence of phaeophytin from injured leaves was demonstrated by the use of spectroscope. Phaeophytin is not present in the case of autumnal colouration, or drought, frost and parasitic injury. It does not arise also in leaves showing symptoms of chronic sulphur dioxide injury" (NRC 1939, p. 54). This method, if generally applicable, will be a handy tool for distinguishing sulphur dioxide injury from other physiogenic disorders in plants.

Recent work of Nielsen, Benedict and Holloman (1954) indicates the possibility of developing an objective method of assessing the responsibility of smog for vegetation damage. They found that when smog-marked leaves were irradiated with near ultra-violet light from a mercury vapour lamp, the marked areas appeared as sharply defined bright pale blue. As the markings caused by hydrogen fluoride, sulphur dioxide, hydrogen sulphide, chlorine, oxides of nitrogen, sulphur trioxide and ozone did not fluoresce under ultra-violet light, this technique may be used to distinguish smog injuries from those caused by other gases. Nielsen, Benedict and Holloman, however, have pointed out that care should be taken to distinguish the smog markings from pure white markings, produced at times with sulphur dioxide and chlorine, which readily reflect light and almost appear to fluoresce under ultra-violet. This is also true of the spotty white, granular injury produced by sulphur trioxide. Further as fungus hyphae and insect deposits also fluoresce blue, it is important to examine the leaves microscopically with visible light.

Criteria for confirmation of diagnosis of diseases produced by pathogenic organisms have been laid down by Koch. To some extent comparable criteria for diagnosis of air pollutant injury in plants seem to be desirable. I consider that (1) the presence of the pollutant in the air, (2) demonstration of distinctive tissue reaction in the plant by objective analytical methods, and (3) experimental production of the symptoms by suitable exposure to the air pollutant, may be collectively employed as criteria to confirm the diagnosis of air pollution injury in plants.

There is, thus, the need for survey, diagnosis and study of plant diseases caused by air pollutants. The pathologists and physiologists must necessarily experiment with new tools and techniques to unravel the various aspects of the problems of production and control of plant diseases arising from air pollution.

VIII. Concluding Remarks

In a brief compass, ladies and gentlemen, I have attempted to unfold before you this morning, the broad aspects of the problems of air pollution in relation to plant diseases. The solution of problems arising from air pollution impinges on diverse fields of scientific endeavour and legislative action. Controlling at source of the pollutants produced as by-products of industrial processes ; the elucidation of the physics and chemistry of the polluted atmosphere ; the evaluation of the weather effects on air pollution epidemiology, are the work of the specialists in their respective fields of study. The aspect of the study of the human and animal health in the polluted atmosphere lie in the domain of medical and veterinary research. The problems of impact of air pollution on damage to vegetation embrace several spheres of botanical research involving concerted efforts of workers in pathology, physiology, ecology and also genetics where radio-active pollutants occur. I may, however, draw your attention to the paucity of records of air pollution damage to plants in India. It is difficult to conceive that the vegetation near industrial centres in this country is entirely free from air pollution damage.

India today is at the threshold of a new industrial revolution. Big devlopement schemes have been launched under the two successive Five Year Plans. New industries are springing up and large factories, refineries and other industrial plants are being constructed in different parts of the country, increasing more than ever before the degree of air pollution and its consequent hazards to plant, animal and human health. Here is then a fruitful field of study, the fundamental aspect of which can hardly be equalled by its economic and social importance.

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SECTION OF ZOOLOGY AND ENTOMOLOGY

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A NEW APPROACH TO HELMINTHOLOGY IN INDIA

INTRODUCTION

It is my proud privilege today to welcome you all to this section of Zoology and Entomology where in the course of the next few days we shall listen to and deliberate upon an array of varied topics presented by savants distinguished for their work in their own fields of speciality. I take this opportunity of expressing my sincere thanks to my colleagues in the Sectional Committee for inviting me to preside over this section.

It is a matter of great satisfaction and encouragement indeed that in our country both men of Science and persons outside the scientific field responsible for framing policy are stressing the need for a re-orientation of research in which all of us are so deeply interested. I have also a passionate desire that we should all make a determined and sustained effort to reconsider the old values and introduce new lines of teaching and research which would enable us to make a fruitful contribution not only to our country but to the world at large. This feeling has prompted me to address you today on a new approach to Helminthology in India, which, I believe, holds out promise of a rich reward.

In choosing this topic, however, I naturally feel diffident, as the problem can be viewed in innumerable aspects while limitations of time permit me to depict a picture which may not seem completely integrated. I may add here that I do not minimize the importance of aspects which may not have been covered in my address.

Helminthology in India has shown a remarkable progress along one main line—viz. the morphology and the systematics of different groups of Helminths. Such studies have their own value and in a vast country like India these are still in great demand. For many a beginner in this field it is still fascinating to find out a *new* species based on the measurement of a few often badly fixed and shrunk specimens showing variations in the size or general topography of the organs. But it is time now that we take stock of things and attempt to modernize the systematics, perhaps by changing the angle from which we have been surveying the group. We might also review the work already done and find out if the deviations in measurement or topography of organs on which specific differentiation is based are not really artificial. It might be still more useful to know if variations in the so-called characters of systematic value are dependent on host differences, or other physiological or ecological factors. The useful work on larval stages and development of helminths which has been carried out in India has solved many problems of life-history. It has often given us clues for the proper control of these parasites. But very little has been done so far on the histopathological, histochemical and physiological aspects of the group. We have hardly begun the study of Phytonematology in right earnest. If by changing our technique of work and employing new experimental methods we can show that the morphological differences in the forms recovered from different hosts are not genotypic but merely phenotypic, we will get a better concept of the so-called species and much of the controversy regarding the validity of species would disappear.

MORPHOLOGY AND SYSTEMATICS

A large amount of work has been done on the morphology and systematics of helminth parasites. Most of the work deals with the study of Trematodes although there has been good bit of work on Cestodes as well. Work on the Nematodes and the Acanthocephala has been comparatively less. Most of the work in morphology and systematics deals with the description of *new* species but attempt has been made to review certain groups. For example, Baylis (1928) and Duthoit (1931) had suggested that the number of ventral glands in Notocotylus increased with the size and maturity of the species. During investigations at Lucknow, Lal (1935-36) reviewed the entire question and found that in several species of this genus the size of trematode and the number of glands did not bear a direct ratio even for examples quoted by Baylis (1928) and Duthoit (1931) themselves.

Recently as a result of study of over 100 specimens of *Stephanostomum baccatum* from a single infection in one sea-raven, Wolfgang (1955) has also demonstrated that most of the so-called characters of systematic value show wide variations and, therefore, cannot be called distinctive. Only the cirrus pouch, the length of the genital atrium, the size of the pharynx and the structure of Mehlis' gland show constancy in this species. The study of the position of the genital pore and a few other characters have enabled a review of the genus *Notocotylus* by Lal (1935), wherein a grouping together of some species of *Notocotylus* by the creation of *Hindia* as distinct from *Notocotylus* was suggested. This has received ample support from various workers and the status of *Hindia* as a sub-genus containing a number of species equal in rank to *Notocotylus* has been recognized (Dubois 1951). Similarly a review of the family Cyclocoelidae by Lal (1936, 1939) cleared up some confusion with regard to the allocation of different genera wherein two diametrically opposed views of Witenberg (1926) and Joyeux and Baer (1927) were prevalent. As a result of these studies (Lal, 1939), the large number of genera of Cyclocoelinae were reduced to four on the basis of the relative position of the gonads and the uterine coils as follows:

1. Ovary in front of two testes which are not separated by uterine coils e.g. *Haematotrephus*. Stossich, 1902, emended Lal, 1936.
   (Syn. *Wardianum* Witenberg, 1926; *Haematoprimum* Witenberg, 1926; *Corpopyrum* Witenberg, 1926 and *Uvitellina* Witenberg, 1926).
2. Ovary in between two testes which are separated by uterine coils e.g. *Cyclocoelum*, Brandes, 1892 emended Lal, 1936.
   (Syn. *Cycloprimum* Witenberg, 1926; *Harrahium* Witenberg, 1926; *Prohyptiasmus* Witenberg, 1926; *Hyptiasmus* Kossack, 1911; *Allopyge* Johnston, 1913 and *Transcoelum* Witenberg, 1926).
3. Ovary behind both testes which are not separated by uterine coils e.g. *Contracoelum* Witenberg, 1926, emended Lal, 1936.
4. Ovary behind both the testes which are separated by uterine coils e.g. *Ophthalmophagus* Stossich, 1902, emended Lal, 1936.
   (Synonym—*Spaniometra*)

In the study of the genus *Levinseniella* it was pointed out that the presence of a cirrus-sac could not be regarded merely as a specific character. Consequently the exclusion of the species *L. adunca*, *L. squatarolae*, *L. cruzi*, *L. jaegerskioldi* and *L. similumus* all possessing a cirrus-sac was suggested (Lal, 1936). Yamaguti (1939) in his revision had agreed with this view and removed his previous species *L. squatarolae* from the genus *Levinseniella.* The creation of a subfamily Maritrematinae Lal, 1937 without a cirrus sac as distinct from Microphallinae Ward, 1901 with a cirrus sac and accepted by various workers [Baer (1943), Dawes (1946)] is based on the validity of this character. In fact Baer (1943) had gone to the extent of suggesting the formation of two separate families—Maritrematidae and Microphallidae. Cable and Kuns (1951) followed by Stunkard (1951) have opposed this separation into two families but have indirectly given further support to the suggestion of Lal (1937) as will be clear from what is given hereafter. Cable and Kuns (1951) have suggested a tentative derivation of the genera *Levinseniella, Carnaeophallus* and *Spelophallus* from the genus *Microphallus*—all these four lacking a cirrus-sac. The genus *Microphallus* is derived from *Maritrema* by a loss of cirrus sac. The genus *Maritrema* on its turn is derived from *Pseudospelotrema,* and *Microphalloides*—these three forms possess a cirrus sac. It is, therefore, evident that there are two distinct groups of these trematodes in the family Microphallidae. This grouping, as shown by Lal (1937), depends upon the presence or absence of a cirrus sac and hence fully justifies the division of the family Microphallidae into two sub-families—Maritrematinae Lal, 1937 and Microphallinae Ward, 1901. With a view to facilitate the revision of the classification of Avian Trematodes Lal (1937) published a paper on the value of different characters in the classification of Avian Trematodes which clearly discussed the relative values of these characters. The same results have been achieved by the valuable researches of Mehra (1931, 1937), Thapar (1925, 1953), Srivastava (1955), Anantaraman (1942) and several other workers in India. I have cited these instances in order to illustrate what a careful review of the already existing species in the light of our increasing knowledge can bring about.

LARVAL STAGES AND DEVELOPMENT

What holds true of the adult forms is equally valid for the larval stages. An interesting example may be quoted of the classification of the Furcocercous Cercariae in which the character of pharynx, the ratio of the lengths of caudal furci and the stem, and the presence of a ventral sucker are taken into account.

Miller (1926) in his comprehensive monograph on the furcocercous cercariae, while recognizing the presence or absence of a pharynx as of greater significance than the presence or absence of a ventral sucker, laid still more emphasis on the character of the tail and maintained a division into longifurcate and brevifurcate groups, both for the pharyngeal and apharyngeal forms. He further emphasized the division by assigning special distinctive features to each group. An impression has been formed, based on limited observations perhaps, that a Schistosome cercaria is brevifurcate and a Strigeid cercaria longifurcate ; but as will be evident from the following account the distinction between these two groups has grown very slender.

Even the fundamental definition of the brevifurcate form with caudal furci less than one-half of the tail stem and longifurcate form with caudal furci longer than one-half of the tail stem is not quite clear. The tail stem and the caudal furci are extremely contractile structures hence it is doubtful if the length of the two structures could be adequately appraised in all cases. Furthermore, Miller (1926) himself has astonishingly assigned to the brevifurcate group *Cercaria elvae* [Synonymous to *C. ocellata* according to Dubois (1929) and Taylor and Baylis (1930)] with caudal furci and tail stem as 328 μ and 501 μ (living material) and 290 μ and 382 μ (balsam preparation) and *Cercaria gigas* with caudal furci and tail stem as 320 μ and 180 μ.

The presence or absence of a pharynx was regarded as a distinctive character for dividing the furcocercous cercariae into two groups—pharyngeal and apharyngeal. Lal (1937) drew attention to the observations of Oiso (1927) regarding the cercaria of *Bilharziella yokogawai* which possesses a muscular pharynx [clearly shown by Oiso (1927) in his diagram] but which is lost during the transformation of tha cercaria into the adult. Quite a number of furcocercous cercariae possess a degenerate pharynx represented only by glandular cell clusters e.g. *Cercaria gracillima* and *Cercaria minor*. This shows the transitory character of the pharynx. *Cercaria multicellulata* is wrongly placed in the pharyngeal group although it does not possess a pharynx.

Porter (1938) gives the measurements of the caudal furci and tail stem in the cercaria of *Bilharziella polonica* as 160 μ and 260 μ. In *Cercaria ocellata* [which Brumpt (1931) showed to be the cercaria of *Trichobilharzia ocellata* as reported by Porter (1938)] the caudal furci and tail stem are 230 μ - 310 μ and 370 μ - 430 μ. Both these Schistosome cercariae are, therefore longifurcate. Talbot (1936) has given the lengths of caudal furci in relation to the tail stem of four Schistosome cercariae and the caudal furci are much too long to bring these cercariae into the brevifurcate group. Macfarlane and Macy (1946) describe long caudal furci in the Schistosome cercaria, *Cercaria oregonensis*.

It can now be pointed out safely that the basis of differentiation into the brevi-furcate and longi-furcate groups representing the Schistosomid and Strigeid groups respectively is not quite in conformity with the available data. Miller's classification has been accepted to date by a large number of workers, though to my mind it has introduced a good deal of confusion in understanding the true affinities of the furco-cercariae. As the mode of future development beyond the cercarial stage in Schistosomes and Strigeids is widely different, the sharply restricted grouping based on the character of the tail which has now been proved to be rather arbitrary involves the risk of misleading workers in the elucidation of the life-cycle of two cercariae which may happen to belong to one and the same family of trematodes though differing in the character of the tail. Our conception, therefore, of a longi-furcate or a brevi-furcate nature of the cercaria in relation to the Schistosomes and Strigeids requires change.

The study of life-history and bionomics of helminths also, requires a bit of re-orientation. Useful work on cercariae in India by Sewell (1922) has been followed by a number of workers and has yielded fruitful results. Studies on the larval stages of Acanthocephala, Cestodes and Nematodes are comparatively few and life-histories of helminths which show some of these interesting stages have to be worked out. Interesting facts can be brought to light if the work is pursued on proper lines. At Lucknow, we have been able to demonstrate not only the occurrence of the miracidia within the sporocysts (Premvati 1955) but have suggested their role in the development—a fact which is of fundamental importance. These miracidia are eyeless but show a general ciliary covering over their body, and four large actively beating flame cells within. Routine silver staining technique marks out 22 epidermal plates arranged in four distinct rows covering the body of these miracidia. The sporocyst containing these miracidia shows the usual structures, germinal epithelial layer, birth opening, flame-cells etc. It is, therefore, certain that the age-long theory of a miracidium larva producing a sporocyst which on its turn may produce daughter sporocysts or redia may not hold good in all cases of development of trematodes. The case under reference is a device for multiple reproduction. How exactly such a state of affairs has been brought about is not yet known? As the germ-ball within the sporocyst may develop into a daughter sporocyst it may pass through a miracidial stage in development which is usually evanescent during normal development. It may be that due to some unknown factor the development of the germ-ball is arrested and not allowed to proceed beyond the miracidial stage. Although experiments on rearing and further development of these miracidia *in vitro* did not succeed, it was observed on more than one occasion that these miracidia showed an elongation of their body giving rise to a structural pattern similar to what would be seen in a miniature sporocyst. Sporocysts were also obtained showing both the daughter sporocysts and the miracidia together within the same body. Cameron (1956) suggests this deviation from the normal life-cycle of trematodes is possible in the specialized family of Strigeids where secondary miracidia may appear in the sporocyst phase.

Work by Byrd & Scofield (1954) on *Ochetosoma ellipticus, Neorenifer aniarum, Neorenifer orula* and *Dasymetra conferta,* has shown how many sporocysts and cercariae can be produced from one single egg. Similarly Read and Voge (1954) have demonstrated how a cysticercoid of *Hymenolepis diminuta* when fed to different animals produces adult cestodes which are different, depending upon the weight, size etc. of the host. Would it not be useful then if a similar experiment is tried in trematodes where a single miracidium may be selected and its future development into cercariae and meta-cercariae noted? Thereafter, the resultant metacercariae may be fed to different hosts and the effect noticed on the morphology of the adults recovered experimentally in this way. It would be interesting to know whether the adult trematodes so obtained would show the same differentiation or similar differentiation as is present in trematodes recovered from natural infections in these animals. Many helminths are not strictly host-specific and may yield to such experiments and develop to maturity in widely different hosts e.g. Birds, Mammals, Reptiles etc. Some work on similar lines has already been carried out. Rausch (1947) demonstrated that sexually mature flukes of the species *Microphallus opacus* which normally occurred in fish could be obtained by feeding the metacercariae to a turtle, a snake or an opossum. These experimentally obtained sexually mature individuals of the same species showed structural diversity. Similarly when metacercariae of *Fasciola hepatica* were fed to a gunieapig, a rabbit or a cow, the adults obtained showed features of differences which were more than what would usually be taken into account for distinguishing species. Such a study if pursued on proper lines would prove whether the so-called different species of a genus of trematode recovered from different hosts are not merely varying phenotypes of one and the same species.

COMPARATIVE HELMINTHOLOGY

Comparative parasitology is a new branch of study and as shown by Baer (1933) and Cameron (1952) when applied to helminth parasites gives us a better idea of the relationship, origin and evolution of the vertebrate hosts lodging these parasites. So far the data regarding the origin and evolution of animals have been derived from a study of Embryology, Comparative Anatomy and Palaentology but even then the picture of evolution is not complete. The study of Comparative Animal Parasitology if pursued properly may often yield fruitful results in completing this picture. As we all know an internal parasite requires some definite biochemical and biophysical conditions for its maintenance within the body of the host. It is also necessary that the physiological requirements of the parasites are flexible but this flexibility can range only within narrow limits with the result that in many a case the parasite can live in a single or only very few related hosts. That is how the parasites become host-specific. Comparative parasitology may show that this host-specificity is a result of evolution and specialization and that the greater the host-specificity the more removed is the parasite from its parent stalk. Similarly the host lodging the parasite may also show divergence from the original stem. Thus a study based on comparative host-specific parasites may be useful in finding out the relative position of the host in the phylogenetic tree. The classical work of Gallien (1935) on *Polystomum integerrimum* in relation to different amphibian hosts is also a pointer in similar direction.

An interesting example may be mentioned of sclerostomes, several closely related species of which occur in the African ostrich and the South-American rhea but none in any other birds. It is also of interest that both the ostrich and the rhea carry the infection of the same species of a tapeworm of the genus *Houttuynia* which is found in no other birds. Thus it is evident that these two birds showing identical helminths, which are not present even in their related Australian ratitae birds viz. the emu and the cassowary have a closely related or common origin and perhaps the one which is distinct from that of the Australian ratitae. Cameron (1956) has pointed out further that the general belief that the American Opossums and Australian marsupials are closely related does not get support from comparative parasitology as the Australian marsupials show a number of sclerostomes but no pinworms while in American opossums there is one pinworm but no sclerostomes. On the other hand the Opossums and Edentates have several common helminths showing thereby that the Opossums and Edentates represent the survivors of a primitive mammalian stock. Perhaps it might be interesting to pursue similar lines of study on Indian helminths thereby showing the value of Comparative Helminthology in understanding the inter-relationship of the tropical fauna.

PLANT PARASITIC NEMATODES

Work on the nematodes which parasitize plants has not been taken up in right earnest in India. Cases of nematode infection are very often confused with fungal diseases as the nematodes may be hidden from sight in the tissues of the plants or very often remain buried deep under the surface layers of earth. It is only during recent years that people have begun to regard phytonematology as an important branch of helminthology having a great economic value. From what is said in the following pages it would be quite clear that there is a great need for studying the relations between the nematodes and the plants. It is only after this has been done satisfactorily that solutions to practical problems of nematode diseases in plants would be found out. Dropkin (1955) has presented an interesting review of these problems.

An important line of work would be to study the level of nematode population in the soil which would affect a plant. An individual nematode may at the most do some damage to a cell or two in its immediate neighbourhood, but because the plant is able to grow out more roots or leaves, the effect of this single individual infection will not be visible. It is only when sufficient number of nematodes are present in the soil and attack a plant that the symptoms of disease make their appearance. We also do not know how the plants would grow in a sterlized soil, with and without the addition of clean infective larvae and even in *Heterodera schachtii* on which extensive and intensive work has been done, critical experiments of growing the host plants in the manner indicated above have not been carried out. We are, therefore, not sure how the levels of nematode infections are related to the symptoms of plant diseases.

Just as it is difficult or rather impossible to free the human population from intestinal nematodes, it is equally impossible to have field soils completely freed from nematode infestations. All that would be possible and useful to know is the optimum level of nematode infection in soils which would not materially affect the crops. Moreover, there may be several other factors which as mentioned by Franklin (1951) for *Heterodera schachtii* would control the plant nematode association. It may also interest us to know that these nematodes do not always damage the plants they infect. In Indonesia it has been seen (Van der Vecht and Bergman, 1952) that moderate *Rodopholus oryzae* infection in rice, although temporarily affecting early growth of plants, ultimately stimulates the recovered plants to yield twice as much as their uninoculated controls. This is so because the retardation in the growth of the infected plant stimulates a rapid development of many rootlets, thereby increasing the nourishment drawing capacity of the plant. Chitwood (1951) and Chitwood et al (1952) showed that tomato, bean and peach plants grew more vigorously with moderate population of soil nematodes than in the absence of nematodes. It may be that here too, a larger number of side rootlets are produced with moderate infection of the main rootlet.

In India taxonomic studies on the nematodes infesting plants and soil are needed as a fundamental part of investigations on this group. A study of predators of these nematodes would also be very fascinating. Cases are on record where some fungi have trapped eelworms by swelling a ring of cells as soon as they came in contact with the nematode which is later surrounded and penetrated by fungal hyphae. Fumigation of soil tends to destroy these nematodes but careful watch is necessary in not allowing these fumigants to release toxic materials in the soil beyond the minimum tolerance limits for the plants. Furthermore, we must know that in attempting to destroy nematodes, there is always a danger of destroying the other micro flora and fauna which may be necessary for the healthy development of plants. The question of biological strains in plant-parasitic nematodes as pointed out by Peters (1955) should also receive our attention. Where morphological distinction is not possible there still may be discernible a difference in the biochemistry of the proteins of these nematodes. Application of serological technique to strain differentiation in plant nematodes may, therefore, prove useful and this would open up a new avenue for investigations in this branch.

The question of imparting training along these lines at the post-graduate level should engage our immediate attention and we should have a department of Nematology with a qualified staff at one of the Universities where it would be possible to train up a band of investigators during the course of next five years.

CONTROL AND ANTHELMINTICS

More and more attention has been paid in recent years to the control of helminthic infection which may be carried out along four main lines (Meleney 1954). These deal with chemotherapy, excreta disposal, protection against infection and eradication of intermediate host. The use of drugs in various helminthic infections in India has been discussed by Bhalerao (1947). Chemotherapy can be useful if applied properly, i.e. in combination with efforts in other directions to control the parasite when it is outside the body of the host. In Canada, the nodular worm of sheep has been almost completely eradicated by the application of the principle of removal of 100% helminths from the entire population of an animal at one treatment or series of treatments. Those parasites which are present outside the body of the host are destroyed by the inclement weather. The sheep are not allowed to leave their sheds during the winter months and are dozed with *phenothiazine* in spring. By the time they are allowed to come out for grazing in summer, the grounds are almost free of parasites which have been killed due to the excessive winter. Thus, these sheep remain free from infection. Why should we not apply similar methods of treatment and controlled grazing to our cattle, sheep and other domesticated animals? Only we should employ the heat of the June Sun for killing eggs and larvae on land instead of the mild cold of our winter. For eradication of the intermediate molluscan host, Copper sulphate has been used but it has not proved of much practical utility. A cheaper and fairly satisfactory method of reducing the number of snail cocoons and developing embryos is to clean the ponds and puddles of floating weeds. With regard to the excreta disposal, various methods have been suggested. Either the excreta is disposed off in a water-carried sewage system or by other well designed method for disposal. If excreta is stored at some place to be utilized as manure, it should be dumped in such a way as to produce natural fermentation and rise in temperature to 110 F. It may also be a useful practice to avoid manuring the land to be ploughed by cattle with cattle excreta manure. Instead horse excreta manure may be used where cattle fodder crops are to be grown and fields ploughed by cattle. Even the untreated excreta may be utilized if need be, but for grounds not open to the species of animals from which this excreta is obtained. This brings us incidentally to another important point i.e., the control of parasites in pastures. We cannot apply chemicals to large tracts of pasture or arable land especially when such areas have to be constantly grazed upon by animals. Rotation of grazing variety of animals may be useful. For example, if a pasture land is once grazed by cattle, the eggs or larvae of worms which mature in these cattle may abound in these places. Such areas may be grazed by horses and vice-versa. This may reduce the rate and frequency of infection as eggs or larvae of parasites of cattle cannot attain maturity in horses. It would thus be a good method of effectively removing the eggs and larval stages from the pastures without detriment to the grazing animals. A number of human helminthic infections have been adequately treated by administration of anthelmintics but more important than the treatment is the prophylactic part. Hookworm, guinea-worm and filaria are common human helminths, infection from which can be easily avoided by observing simple sanitary and hygienic precautions. Conservancy conveniences, treatment of drinking water and anti-malarial campaigns would gradually improve conditions, but scattered and local attempts to improve sanitation would be of no value to an uneducated human population allowed to move about freely.

One of the sources of widespread faecal contamination in spite of all efforts for improving sanitation is from the railway trains in India as the railways permit pollution of their tracks and do not meet this nuisance in the manner it has been done in some other countries. Control of helminth parasites, therefore, requires a nation-wide policy and public opinion should be educated to see that a central authority for legislation is appointed for the purpose.

Although valuable information is available on the treatment of helminthic infection in most cases of trematodes, cestodes and nematodes, very little work on treatment and control of the acanthocephalan infection in man and animals has been carried out. The only proper treatment recommended for *Macracanthorhynchus* infection is administration of *Sodium flouride* (Chandler 1954) but even this is not supposed to be effective. Lal (1947) demonstrated a simple method of maintaining *Echinorhynchus truttae* in a physiologically fit condition in various saline media for a number of days and worked out the effect of different known anthelmintic substances on these acanthocephalans *in vitro*. It was demonstrated that carbon tetrachloride, thymol and copper sulphate proved fatal to the parasites at a concentration of 0·05% while oil of Chenopodium killed the parasites at a concentration of 0·1%. It may be hoped that the results obtained *in vitro* would perhaps with slight deviation hold good for treatment *in vivo*, not only for the species in question but also to some extent in allied cases of acanthocephalan infection.

I would like to emphasize here India's potential resources with regard to the anthelmintics. This point has been touched by Thapar (1937), Shirlaw (1940), Krishnaswamy (1941) but not stressed in the manner desirable. Chopra and Chandler (1928) gave a detailed account of some anthelmintics used in the Indian system of medicine. A number of synthetic drugs have also been suggested by Trivedi and Nargund (1941), Paranjpe et al (1945). The writer in the course of his observations has come across references to the so-called indigenous anthelmintics but their efficacy can be tested only in carefully planned experiments. On a review of the ancient Ayurvedic books (Atharvaveda, Sushruta samhita, Kashyap samhita, Ashwa Vaidyaka, Hasta Ayurveda, Madhav nidan, Sharangdhar samagrah, Charak samhita etc. etc.), it is observed that there is an entire group of drugs known as "Krimighna-varga" which are said to be specific for the removal of Krimi (helminth). A number of plants, some metals and a few non-metals are mentioned as "Krimighnavarg" drugs.

Some of these plants may be mentioned here.

	DRUGS	BOTANICAL NAMES
1.	*"Vidanga"*	*Embelia ribes.*
2.	*"Mandalia" or "Mandla or "Pangra"*	*Erythrina indica.*
3.	*"Pushkarmool"* or *"Kain"*	*Costus speciosus.*
4.	*"Palas"*	*Butea frondosa.*
5.	*"Dadim"*	*Punica granatum.*
6.	*"Sobhanjan"* or *"Sahjan"*	*Moringa pterygosperma.*
7.	*"Manjista"* or *"Manjith"*	*Rubia cordifolia.*
8.	*"Indurkani"*	*Ipomoea reniformis* or *Salvinia cucullata.*
9.	*"Chitramula"* or *"Chitrak"*	*Plumbago zeylonica.*
10.	*"Bathua" or "Vastuk"*	*Chenopodium album.*
11.	*"Supari"* or *"Pungiphal"*	*Areca catechu.*

Besides these plants, various metals and non-metals were used as anthelmintics by the ancient people of India, viz. Ashes of Iron, Mercury, Calomel, Mica, Galena, Tin, Lead, Copper, Realgar (Arsenic 70% + Sulphur 30%) and Sulphur. Some of the modern anthelmintics are derivatives of substances like Arsenic, Copper, Calomel, Areca and Chenopodium, all of which, as will be evident now, have been in use in ancient India from times immemorial. It is very likely that if the indigenous anthelmintics are chemically analysed and their therapeutic properties studied, it would be possible to add materially to India's contribution to anthelmintic medication. It is evident from a review of the ancient Ayurvedic literature that raw extracts and juices of various special parts of the plants were used, but invariably these were administered along with other drugs in the form of decoctions or pastes. The modern anthelmintic medication as formulated by Hall (1919-26) and co-workers suggests a frontal, a rear and a flank attack. Remarkable similarity to the modern method is noticeable in the use of oral medication of the ancients (=frontal attack of modern oral medication), and in the use of *"vastis"* (rectal clysters) which is a mode of administration of medicines into the rectum and large intestine of men and animals (=rear attack of modern enema treatment). But the most important and in a way the most surprising of all is the ancient method of applying a flank attack (which according to modern workers takes the form of subcutaneous, intra-muscular and intravenous injections of anthelmintics). The use of a hypodermic syringe was perhaps unknown in those days but the drugs were applied to parts of the body scarified by razor or an ordinary needle point was utilized for probing medicine into the interior of the scarified part, followed by a gentle massage with fingers, (vide "Sharangdhar samagraha").

HISTOPATHOLOGY

Another interesting line of work which has assumed great importance in recent years is histopathology of helminthic infections. Histopathological changes of this type have been generally studied by various workers in man and vertebrate animals. In India, however, such studies are few and much less on the invertebrate hosts. Some of these studies pertain to blood-fluke infection in vertebrate tissue (Datta, 1932, 1933, Rao 1933, 1934, Lal 1937). Lal and Baugh (1955) and Lal and Premvati (1955) have extended the histopathological work in the invertebrate hosts and have shown in detail how the infection of the snail by trematode larvae affects the life of the host. Such studies have an economic value as the snails serve as intermediate hosts for the trematodes. In the digestive gland of the snails, the cells lose their characteristic columnar arrangement, transverse partitions in the cells are laid down and the columnar tissue may even present a squamous appearance. Histolysis of the cells, loss of contained calcium globules and cell granules and consequent impairment of normal metabolic activity of the snail may take place.

In the infected *Melanoides tuberculatus,* Lal and Premvati (1955) demonstrated that in the so-called triangular cells (=calcium cell of Van Weel, 1950) of the digestive gland of the snail there is a total disappearance of the calcium globules. As the shell of the snail which contains calcium salts helps in buffering the acidic products of anaerobiosis (Culbreth, 1941 ; Robertson, 1941), the acidity of the hepatic tubules in the digestive gland is similarly neutralized by the calcium globules contained within the triangular cells and this helps to maintain a constant pH in the inside of the snail. It is evident, therefore, that in such infections, loss of calcium globules is enormous and the available calcium remains much below the normal level. In *Vivipara bengalensis* it was shown by Lal and Baugh (1955) that the development and growth of metacercaria affected the normal functioning of its organs. In the mantle, the infection retarded its normal elastic function. In the tentacle, it is likely to interfere with its normal sensory function. The optic nerve which innervates the organ of vision traverses through the basal part of each tentacle and with the growth of the meta-cercarial cysts the optic nerve undergoes pressure atrophy and affects the vision of the host. Also the fertilizing power of the male snail is affected. In the gill region, the usual course of blood circulation and consequently respiratory function would be affected. It would, therefore, be interesting to pursue work on these or similar lines. The castration of gonads and the reduction in the size of the male copulatory organ would bring about a change of sex in these snails and impede their normal procreative activities thereby reducing the snail population in the long run. Lal (1953) has shown how the metacercarial (*Diplostomulum*) infection in trout may cause a reduction in the size of the lens of the eye, thus affecting the vision in the fish. Crofton and Fraeser (1954) have described encysted metacercaria in the spinal nerves of the tail region, but Lal had earlier suggested how the disintegration of the tissue in the spinal nerves of the tail of *Gadus oeglofinus* due to metacercarial infection may bring about a paralysis of the tail muscles and consequent retardation in the swimming power of the fish.

Histopathological studies in cases of infection by cestodes, nematodes and acanthocephala present a similar picture. The infection of *Leuciscus rutilus* by *Ligula* and of *Gasterosteus aculeatus* by *Schistocephalus* cause a modification of the gonads of fishes so that these do not show later maturation stages and appear to be like those in spent fish. Rausch (1953) reported cases of histopathological changes induced in the alimentary canal of the sea-otter by infection of the nematode, *Porrocaecum* and the acanthocephalan, *Corynosoma*.

Dropkin (1955) has classified the cytopathological changes in plants due to nematode infection as 1) Cell hyperatrophy, 2) Cell hyperplasia and 3) Cell necrosis. The cell-wall partitions are broken down and syncytial giant cell-masses are formed wherein the nuclei attain a much larger size. It is agreed that the production of giant cells is in some way related to the secretions from the nematode mouth. Perhaps the nematode uses its stylet to puncture the cells near it and discharges some secretion from its oesophagus into these cells which are thereby stimulated to abnormal growth. Christie (1936) also thought that the stimulus for gigantism emanates from the head of the nematode.

HISTOCHEMISTRY AND PHYSIOLOGY

Similarly there is a real need for histochemical and physiological studies on helminths. Pearse (1953) has well said that Histochemistry can transform the descriptive science of Biology into a dynamic and functional science complimentary to Physiology and Bio-Chemistry. There is no doubt that the histochemical methods of study of helminths have cleared up various functional obscurities of these worms. Johri and Smyth (1956) have suggested that histochemical methods can also find application in the clarification of morphological details, as seen in whole mounts or in sections. Let us take an example. There has been some controversy with regard to the mode of formation of the shell of the eggs in Trematodes or Cestodes. Smyth (1951) has summed up his work on Cestode physiology

(Smyth 1950) and has clearly shown that by using a stain absolutely specific for the shell-material of the eggs (viz. Malachite green giving a brilliant green colour and Methyl green giving greenish-blue colour), the gland or ducts through which the shell-material is secreted or passed may readily be identified in sections, and the egg-shell material may be followed up from its place of origin to the place where it actually forms a shell for the egg. Results obtained in this connection clearly show that the shell-material is not produced in trematodes in the Mehlis's gland, (the so-called shell-gland) in the classical way as understood by us so far but that it is produced in the vitelline glands. Stephenson (1947) has already given evidence in support of this contention and has shown that the egg-shell is an Ortho-dihydroxyphenol-protein complex.

Smyth (1951) has further shown that the same holds good for pseudophyllidean cestodes where, in the three members of the Diphyllobothriidae —*Schistocephalus, Ligula* and *Diphyllobothrium,* he has demonstrated that the so-called vitelline glands secrete both yolk and shell-gland material. In Cyclophyllidean cestodes, there is no external egg-shell present in eggs and the use of methyl green technique clearly reveals in *Taenia* the absence of any shell material in the vitelline cells.

Thus a great contrast is seen in the function of the vitelline glands in these two groups of cestodes. Smyth (1951) has suggested that the use of the term *"Vitelline glands"* should be restricted (in order to remove any confusion or doubt) to only those cases where these glands produce only yolk and introduce a new term *"Vitellocalycal glands"* for forms like pseudophyllidean cestodes or trematodes where these glands produce both yolk and shell material. The nomenclature "Shell-gland" should be dropped and replaced in all entirety by "Mehlis's gland".

Similar results can be obtained by using Catechol by which the two portions of the vitelline gland cells yielding yolk and shell material can be differentiated. This has been observed in our work on *Fasciola indica* at Lucknow. Johri and Smyth (1956) have demonstrated the distribution of the enzyme polyphenol oxidase in the strobilae of *Schistocephalus* matured *in vitro*. The polyphenol oxidase, which is richly present in the vitelline glands at the end of 36 hours of incubation of *Schistocephalus,* appears to be utilized and carried into the uterus during egg formation, so that at the end of 72 hours of incubation the uterus shows a brilliant reaction with Catechol and the vitellaria show an almost negative reaction.

It has also been possible to demonstrate the activity of phosphatases, enzymes which hydrolyse esters of phosphoric acid and which play their part in the carbohydrate metabolism of helminths. In our work at Lucknow we have obtained interesting results and although the data obtained so far are meagre this field of investigation appears to be full of promise. Similarly it would be quite interesting to employ methods of histochemical preparations and enzyme analysis to determine the nature of the secretions produced from the head of a nematode causing gigantism of cells and their nuclei in the plants.

The study of the nature of pigments in parasites shows how these may in some way be related to the respiration of these endoparasites. There is a belief that pigmentation in parasites depends upon the uptake of the coloured food material. This is not correct. The red juvenile *Polymorphus* accumulates orange red fat globules from the colourless body fluid of *Gammarus* and an interesting species of *Bolbosoma* shows in the same host a red colour in small intestine but white in the large intestine. During our investigations at Lucknow it has been possible to report upon a red pigment in a species of *Gastrothylax* which on chemical analysis showed an iron-containing protein with two absorption bands ranging between 5850 Å—5735 Å and 5535 Å—5410 Å (diffuse) with peaks of absorption at 5450 Å and 5750 Å. These bands can be compared favourably with the *Nippostrongylus* haemoglobin-band (Davenport, 1949) and with the two bands at 5370 A and 5650 A in the alkaline Methaemoglobin of *Ascaris* (Davenport 1949). Among the invertebrates generally, the haemoglobin shows irregular distribution as it may be lacking in some phyla and only of sporadic occurrence in others, or even replaced by allied pigments. Weinland (1901) suggested that *Ascaris lumbricoides* was an obligate anaerobic parasite but Lasser (1944) reviewed the controversy and showed that the parasite was not completely independent of a supply of Oxygen. In fact the occurrence of haemoglobin in helminths has been regarded as an evidence for their utilizing the oxidative enzyme systems in their body. It was Keilin (1925) who first demonstrated that *Ascaris lumbricoides* contained two different haemoglobins which could be distinguished spectroscopically from each other and both from the host haemoglobin. Similarly it has been seen in *Nippostrongylus* and *Strongylus* that the haemoglobins have great affinity for oxygen although the haemoglobin of *Strongylus* differs from that of *Nippostrongylus* in not being essentially respiratory.

This brings us to another important line of helminth study viz. its physiological aspect. This study has been gaining momentum and during the last two decades has assumed paramount importance. Von Brand (1952) has very ably surveyed the earlier work on the chemical physiology of endoparasitic animals thereby focussing the attention of biochemists on the parasitological physiology. The histochemical methods of studying helminthic behaviour, the relation of endocrines to the activity of parasites, the physiological basis of chemotherapy, the metabolic disturbances caused by helminthic infection, the histopathological conditions and the *in vitro* development, growth, or maintenance of endo-parasites are all co-ordinated in the larger study of parasitological physiology. The introduction of experimental methods will help to probe deeper into the complex problems of these endo-parasites and throw a flood of light on them and reveal the mysteries of their life-processes.

Conclusion

This brief survey of some important aspects of Helminthology would have revealed the lacunae which are present in our existing knowledge of the group. We might, therefore, re-orientate our teaching and research in various ways so as to improve the quality of work and open up new fields of investigation simultaneously with the modernizing of the old techniques. We must also bear in mind that what is true of helminthological research would in a greater or lesser degree apply equally well to other branches of Zoology. The subject of Zoology has reached such unwieldy proportions that we cannot make progress without the growing specialization which it demands. It is high time that we learn to work more and more in co-operation with specialists in other allied branches of Science. The older Zoologist could be individualistic but though he could take a generalized view of the subject in all its bearings he could not probe deeper into the why and how of animal structure and function. The modern Zoologist is a specialist who, by drawing regularly upon the resources of a chemist, a physicist or a statistician, can dive deeper into the processes of life although he cannot have a complete view of the subject like his predecessor ; only if such contacts with the other fields of Science are lost, the subject will be in danger of becoming static. This danger, however, can be averted by selecting border line topics for seminars and symposia in which scientists from various fields of activity can be brought together with mutual advantage. In fact, this has been the work of the Indian Science Congress for quite a few years now and in its popularity today lies the proof of its virtue. As a teacher at one of the Universities, I shall be failing in my duty if I do not take this opportunity to emphasize the need for a re-orientation of our teaching of Helminthology or Zoology as a whole. Though it is not possible for a Zoologist to know in detail the technique of Physics and Chemistry it would be of distinct advantage if he could understand their fundamentals and learn enough of these to incorporate them in his own work. This brings us to the important problem of necessary modifications in our University curricula with a view to enable our graduates to understand the place of modern technique in the study of their subject. Many of the questions now set at the University examinations are based on what has been achieved by experimental methods during the last two or three decades. While results of such new researches, which are increasing every day, should be undoubtedly incorporated in the courses of study, judicious pruning of the already existing syllabus should also be carried out. Unless this is done our graduate will not be able to grasp the subject properly and will have a blurred vision of the overcrowded syllabus. This would be reflected (and, in fact, is already being reflected) in the sketchy background of the post-graduate and research students who are joining our Universities today. It is time, therefore, that we ponder over the whole question and in view of the importance of this new approach to the subject take the necessary steps to improve our methods of teaching and research.

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SECTION OF ANTHROPOLOGY AND ARCHÆOLOGY

President :—M. N. SRINIVAS

PRESIDENTIAL ADDRESS

CASTE IN MODERN INDIA

I am deeply grateful to you for electing me as President of the Section of Archaeology and Anthropology of the Forty-fourth Session of the Indian Science Congress Association.

As you are doubtless aware the subject of my address is too vast and complex to be adequately tackled within the limited time at my disposal. I shall only be able to touch on a few aspects of it and that too only in a perfunctory manner. My main aim in this address is to marshal evidence before you to prove that in the last century or more, caste has become much more powerful in certain respects, than it ever was in pre-British times. Universal adult franchise and the provision of safeguards for backward groups in our Constitution have strengthened caste appreciably. The recent strengthening of caste contrasts with the aim of bringing about a 'casteless and classless society' which most political parties, including the Indian National Congress, profess.

I

The political system of pre-British India was characterized by clear territorial cleavages marking off the territory of one chieftain or raja from the territories of others. Usually, above the chieftain or the raja, there was the viceroy of an emperor or the emperor himself, and below the chief were the headmen of single villages. The boundaries of a chief's or raja's domain were mobile, being subject to expansion or contraction depending upon the military prowess of the chief *vis-a-vis* other chiefs, and also upon the firmness with which the viceroy or emperor exercised his control. However, while the boundaries were mobile over a period of time, at any single moment they constituted effective barriers between people living in different chiefdoms. Such a political system naturally imposed severe limits on the horizontal extension of caste ties. In short, political frontiers determined the effective, if not the maximum, social space of each caste living within them.[1] The fact that over a period of time the boundaries were mobile meant that cultural ties frequently cut across the existing political boundaries. The coincidence of the cultural and political frontiers which is explicitly recognised in the *Report of the*

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[1] In Kerala, however, the Nambutri Brahmins were superior to the territorial cleavages. See Dr. E. Miller's essay "Village Structure in North Kerala" in *India's Villages,* West Bengal Government Press, Calcutta, 1955.

States Reorganization Commission is, on the whole, a new event in Indian history.

A natural consequence of the territorial limits imposed by the political system on the horizontal tendency of castes was the stimulus it gave to castes living in an area to cooperate with each other. Occupational specialization stressed this interdependence as each caste was dependent for its livelihood on the work done by the other castes. Again, the fact that the members of a caste were all competitors for the goods and services offered by the other castes, meant that relations between the former were frequently one of conflict. This tendency of economic ties to cut across caste barriers was also supported by political and religious ties. It was the establishment of *Pax Brittanica* which set the castes free from the territorial limitations inherent in the pre-British political system. British rule freed the jinn from the bottle.

The building of roads all over India, and the introduction of railways, postage, telegraph, cheap paper, and printing—especially in the regional languages—enabled castes to organize as they had never done before. A postcard carried news of a caste meeting, and the railway enabled members scattered in far-flung villages to come together when necessary, while the availability of cheap newsprint facilitated the founding of caste journals, the aim of which was to promote the interests of their respective castes. It is usual to point out that railways and factories relaxed rules of pollution regarding eating and drinking and other forms of contact. But that is only one side of the story. The availability of cheap paper enabled caste disputes to be recorded, and this gave permanent form to rules and precedents which were till then dependent upon the fallible, and therefore challengeable, memory of elders. I learn that several castes in Gujarat have had their 'Constitutions' printed.

The effects of British rule upon the caste system have been discussed at some length in Prof. G. S. Ghurye's book, *Caste and Class in India,* (Philosophical Library, New York, 1952) and I do not propose to cover the same ground as he has done and in such as an able manner. In fact, I shall draw freely upon the material brought to light by him to make my points.

It is widely held that the civil and penal codes introduced by the British over the sub-continent of India took away much of the power previously exercised by caste panchayats. The British also introduced a new principle of justice, viz., that all men are equal before the law, and that the nature of a wrong is not affected by the caste of the person who is committing it or by the caste of the person against whom it is committed. It is necessary to emphasize in this connection that the use of law courts by some peasants did not put an end to caste panchayats. The peasants made use of both the systems of justice. The traditional panchayats, caste as well as village, are still functioning in many parts of the country. This fact is specially relevant in all schemes for the revitalization of panchayats. In certain parts of the country, British rule set in motion economic forces which upset the traditional hierarchy but this did not mean that caste was weakened thereby. In fact, it is arguable whether such a disturbance did not actually increase caste consciousness all round. A low caste which made money as a result of new opportunities presenting themselves to it, made attempts to raise its status *vis-a-vis* other castes, and this resulted in opposition from the latter. Even eventual consent to such a claim did not lessen immediate opposition. Again, it is important to note that the newly-rich castes only pressed for a higher status for themselves—they did not urge that the caste system should be thrown aside. It is true that the economic forces released under British rule resulted in greater mobility within the caste system, but that is quite different from making progress towards an equalitarian society. There is no doubt, however, that increased mobility also meant that caste consciousness increased.

I would like to refer in this connection to Dr. F. G. Bailey's study of an Orissa village. Dr. Bailey did his field-work during 1952-54, and his book is in the press at present. I am grateful to Dr. Bailey for giving me permission to refer to his unpublished data here.

In the village studied by Dr. Bailey, the policy of the then Government of Bengal—Orissa was formerly a part of Bengal—regarding the sale of liquor resulted in the sudden enrichment of two low, immigrant castes, the Boad Distillers and the Ganjam Distillers. The prosperity of these two groups resulted in disequilibrium as they both wanted to lay claim to having higher status than before. Previously, in that village, the Warriors owned all the land, but by 1910 when prohibition was introduced, the Boad Distillers owned as much land as the Warriors and the Ganjam Distillers owned more land than any one else. The acquisition of land by the two castes was followed by the Sanskritization of their custom, ritual and way of life, and all this was part of the process of stating their claim to being a high caste.

While the two Distiller castes have succeeded in raising themselves up, the Boad Outcastes, an immigrant Untouchable caste, the members of which made money by trading in hides, found that Sanskritisation did not help them. Their claims for a higher position in the hierarchy are opposed by everyone including other Untouchable groups such as the Sweepers whose economic position has not improved. The Boad Outcastes are getting increasingly estranged from all local castes and they are seeking the help of officials and law courts to secure the rights which the Constitution of this country guarantees to them. The special difficulties in the way of the Untouchables' raising their collective status heighten inter-caste tensions.

Increased economic mobility led to increased social mobility and the traditional process of Sanskritization ensured that such mobility did not lead to revolution. But Untouchables by and large seem to be unable to take advantage of it. This is one indication that the problem of the Untouchables is different from that of the other low castes ; the latter have a means of pushing themselves up in the system while the former do not. The decennial census, introduced by the British, recorded caste, and it unwittingly came to the aid of social mobility. Prosperous low castes, and even those which were not prosperous, sought to call themselves by new and high-sounding Sanskrit names. The recording of these names in the census was part of the struggle to achieve a higher status than before. Thus the census provided a new field for caste conflict.

II

While British rule occasionally did confer economic benefits on low castes, it was more usual for these benefits to go to the castes which already stood at the top of the hierarchy. It must be remembered that in the examples we have cited above, ideas regarding pollution prevented the higher castes from getting into the liquor and hides trade. In other words, the institution of caste came in the way of their benefitting from the new economic opportunities. But the same institution benefitted the higher castes in certain other fields. Western education provided an indispensable passport to these fields, and the high castes which had a tradition of literacy, such as the Brahmin, Vaishya and Kayastha, were in a more advantageous position to exploit the new opportunities than those which did not have such a tradition. Members from the former privileged castes became clerks, schoolmasters, officials, lawyers and doctors. The Vaishyas or Banias naturally led the other castes in taking advantage of the new commercial opportunities offered by British rule. The bulk of the new intelligentsia came from the three groups of castes and the leadership of the nationalist movement fell mainly upon their shoulders. It is not surprising that they were disliked by the British rulers. The upper castes were not only the first nationalists but they were also conscious of the fact they were Hindus. This was specially true of the Brahmin who enjoyed a privileged position as priest. European missionaries have abundantly testified to the hold the Brahmin had over the bulk of the Hindus and this hold had to be broken if Christianity had to make headway in India.

The point I wish to make is that the policy pursued by the British Government in India of giving preference to the low castes was not only in accordance with its humanitarian sentiments but it had also the effect of making the lower castes look upto the British for protection. It drove a wedge between the higher and lower castes and this was specially seen in peninsular India. The leaders of the non-Brahmin parties in the twenties and thirties aimed at a union of Christians, Muslims, Hindu non-Brahmins and the British rulers against the Brahmins and the other high castes who were to be found in the nationalist movement. It was Mahatma Gandhi who was chiefly responsible for carrying nationalism to all sections of the population.

III

Prof. Ghurye describes that before the Indian Mutiny of 1857, the Bengal Army was composed largely of Brahmins and Rajputs, and that soldiers belonging to these castes took a leading part in the Mutiny. Soon there was clamour in England to rid the army of the higher castes. Soon after the Mutiny, a Commission was appointed under Lord Peel to go into the question of the reorganization of the Indian Army. The Commission, after recording evidence from high British officials who had served in India, recommended that "the native Indian Army should be composed of different nationalities and castes and as a general rule mixed promiscuously through each regiment." Ever since then the Indian Army has been steadily purged of the higher castes. Prof. Ghurye thinks that the Mutiny drove home to the British rulers that the safety of British dominion in India was very closely connected with keeping the Indian people divided on the lines of caste. He quotes the opinions of contemporary Britons like Sir Lepel Griffin and James Kerr who knew that caste divided the Indian people into small groups and obstructed the emergence of a nationalist sentiment. Towards the last quarter of the nineteenth century, the maxim of 'Divide and Rule' began to be openly preached by historians and journalists.[3]

Throughout Indian history attempts have been made to reject Brahminical supremacy, but the non-Brahmin movement of the present century differs from earlier movements not only in regard to scale and intensity but also as to ideology. The speeches made by the leaders of the non-

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[3] Ghurye, *Op. cit.*, pp. 175-6.

Brahmin movement in Madras in the twenties, for instance, reveal the influence of liberal and radical thought of Western Europe.[3]

The non-Brahmin leaders asserted that they were as good as the Brahmins, and that they wanted the British rulers to give them preferential treatment for a time in order that this could become an established fact. It is not certain to what extent the leaders of the non-Brahmin movement in the first quarter of this century were influenced by Western rationalist thought. The Dravida Kazhagam, and its off-shoot, the Dravida Munnetra Kazhagam, both profess to be atheistic, but it is not known to what extent this is shared by the followers of these two militant movements.

The non-Brahmin movement of peninsular India was the response of a downtrodden section of Hindu society to the challenge of caste in the new context of British rule and Western liberal-rationalist ideology. One of the founders of this movement was Jyotirao Phule, of Poona, a man of the Gardener caste, who founded the Satya Shodak Samaj in 1873 with the object of asserting the worth of a human being irrespective of his birth in a particular caste. In certain respects, Phule's reforms anticipate the programme of the non-Brahmin movement in Madras. He urged the non-Brahmins not to engage Brahmin priests to conduct the ritual of non-Brahmins. He saw the need for education of the non-Brahmins, and in 1848 he started a school for non-Brahmin boys and girls. In 1851, he started a school for Untouchables in Poona. He demanded adequate representation for members of all castes in the services and local bodies.

The measures which Phule advocated in the second and third quarters of the nineteenth century were to become the main planks in the programme of the non-Brahmin parties of Bombay and Madras in the first half of this century. Prof. Ghurye records that Phule's demand for special representation for non-Brahmins in the services and local bodies went unheeded till the last decade of the nineteenth century when the Maharaja of Kolhapur (Sri Sahu Chatrapati) took up the non-Brahmin cause. Thanks mainly to his efforts, special representation through mixed electorates was conceded to the non-Brahmins in the Montague-Chelmsford Reforms. These reforms divided the people of Bombay into three political tiers, the first tier consisting of Brahmins and Allied Castes, second the Intermediate Castes which included the Marathas and others, and finally, the Backward Classes including Untouchables. This principle was also made use of in appointments to Government posts. Prof. Ghurye quotes a resolution of the Finance Department of the Government of Bombay, dated 17th September 1923, prohibiting the recruitment of Brahmins and Allied Castes to the lower services, till a certain proportion of the posts were held by the Intermediate and Backward Castes. This policy of reserving a certain percentage of the posts to the non-Brahmin castes was followered by other provincial governments too. The logical consequence of this policy was seen in Madras as early as 1924. "The hundreds of small communities into which Indian society is divided were not slow to take advantage of the opportunity which was so conveniently afforded them, and began to clamour for special representation in the legislature, local bodies, the public services and even educational institutions. The Government, in which also the non-Brahmin element was very influential, tried to satisfy the ever-increasing demand for the plums of office, but naturally could not succeed. It created jealousies and enmities which have now reacted with disastrous effect on the party (the non-Brahmin Party)."[4] At the same time the Chairman of the Reception Committee of the Meeting of the Madras Non-Brahmin Party in 1924, made a strong appeal "to abandon the communal policy pursued hitherto and to transform the party into an organization representing the forces working for reform along constitutional lines into which everyone without distinction of caste, religion or colour would have free admission."[5] Twelve years later, in the 1936-37 elections, the non-Brahmin Party suffered a decisive defeat at the hands of the Congress. This happened in both Madras and Bombay but it did not mean, however, that the non-Brahmin movement came to an end. The more moderate non-Brahmins entered the Congress and soon dominated it. In Madras the extreme non-Brahmins under the leadership of Sri E. V. Ramaswamy Naicker joined the Dravida Kazhagam, a militant, atheist, anti-Aryan, anti-North Indian, anti-Hindu and anti-Brahmin movement. The Dravida Munnetra Kazhagam claims to be more 'progressive' than its parent, admitting even Brahmins as members. It is pro-nationalization and anti-landlord in outlook.

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[3] See the *Proceedings of the First Provincial Conference of the League of Non-Brahmin Youth (Central), Madras, 1927; and the Administrative Report of the League of Non-Brahmin Youth, Madras, 1926-27.*

One feature of the peninsular non-Brahmin movement may be disposed of now alone. The unifying feature of that movement was dislike of, if not hatred for, the Brahmin. Right up to the beginning of the First World War the Brahmins dominated the administration and the liberal professions everywhere in peninsular India excepting Kerala. It is alleged that during the period of Brahminical domination, favouritism towards Brahmins and discrimination against non-Brahmins, were both widespread. When power and influence passed into the hands of the non-Brahmins they seem to have harassed the Brahmins over whom they have power. Prof. Ghurye quotes from the memorandum of the Government of Bombay to the Indian Statutory Commission in 1928 to show that in those District School Boards in which the non-Brahmins were in a majority, attempts were made to oust Brahmins regardless of all consideration for efficiency.[6] Anti-Brahminism assumed a violent form in the riots which occurred in Kolhapur and elsewhere following the assassination of Mahatma Gandhi. Anti-Brahmin demonstrations, the looting and burning of Brahmin houses, printing presses, factories and shops. The Brahmin-owned and—edited Marathi press had been very critical of Mahatma Gandhi.[7]

Sri A. B. Lotthe, one of the leaders of the non-Brahmin movement in Bombay in the twenties and thirties, commented on the riots: "As an humble friend of the non-Brahmin movement of thirty years ago, I still think (that) the movement was essentially justified, but later on it degenerated into the naked communalism of several non-Brahmin communities which ultimately broke it up. The vicarious punishment of all the Brahmins for the sins of a few among them is foolish, and hatred of one community against another is suicidal to democracy. The days of caste oligarchies have gone and cannot and ought not to be revived. Those in the State who encourage narrow communal pride are the worst enemies of the people and the State."[8]

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[4] Quoted from the *Indian Daily Mail*, Bombay, 1924. See Ghurye *Op. cit.*, p. 183.

[5] See the *Administrative Report of the League of Non-Brahmin Youth*, Madras, 1926-27, and the *Proceedings of the First Provincial Conference of the League of Non-Brahmin Youth (Central), Madras, 1927.* (See also N. Rama Rao, *Kelavu Nenapugaḷu*, Bangalore, 1954, p. 11.)

[6] *Op. cit.* p. 175 ; and p. 183.

[7] See Miss M. L. P. Patterson's "Caste and Politics in Maharashtra" in the *Economic Weekly*, VI-39, 25th September 1954.

[8] Ghurye, *Op. cit.*, p. 202.

IV

I shall now try to demonstrate that the power and activity of caste has increased in proportion as political power passed increasingly to the people from the rulers. The transfer of power to the people began under the British, and it finds its culmination in the Constitution of the Republic of India under which every adult has a vote which is exercised quinquennially at the elections. I shall consider each linguistic region of peninsular India and then refer briefly, and I am certain, very inadequately, to India north of the Vindhyas. It is hardly necessary for me to add that this is due to my ignorance of the North and to nothing else.

The non-Brahmin movement in peninsular India is over a century old. I have already mentioned Phule's efforts in Poona in the 1840s. About the same time in Madras, the artisan castes made a representation to the Board of Revenue to the effect that all men should be appointed to public offices without distinction and to the destruction of Brahminical monopoly.[9] The movement gathered strength slowly. According to Prof. Ghurye, Phule's ideas did not make progress with non-Brahmins for several years after he had propounded them.[9] Caste consciousness seems to have suddenly become sharp in 1916 when Montague arrived in India to consult the people and the Government of India about the future form of Government. But the Montague-Chelmsford Reforms were not announced till after the end of the First World War. Non-Brahmin leaders in peninsular India felt that the granting of power to their countrymen might lead to Brahminical tyranny. The Maharaja of Kolhapur pleaded before the announcement of the Montague-Chelmsford Reforms for "Communal Representation" for at least ten years if Home Rule was not to culminate in oligarchy.[10] On the occasion of the celebration of the tenth birthday of the Madras Non-Brahmin party paper, *Justice*, the Raja of Panagal declared that at the conclusion of the First World War, the non-Brahmin leaders felt that a certain amount of political power would be given by the British to Indians. "The late leaders felt that before any political power is conceded to the people, the latter or a majority of them must be in a position to assert themselves against any one community which would try to appropriate it to itself."[11] That watch-dog of non-Brahmin interests, the newspaper *Justice*, was founded on 26th February 1917, and it was followed by the starting of other similar newspapers, *Kudiarasu* and *Dravidar* (Tamil), and *Samadarshini* (Telugu). The inter-war years may be described as a period of intense non-Brahminism in the South. The leaders of the non-Brahmin party collaborated with the Government, and took measures to reserve a certain percentage of posts in the administration and seats in the local bodies and legislatures for the non-Brahmins. The principle of reservation was also extended to seats in educational institutions.

V

In a penetrating article on "Caste and Politics in Maharashtra". Miss Maureen Patterson has analysed the forces of caste underlying politics in Maharashtra (excluding Vidarbha and Marathwada).[12] Miss Patterson discusses the part played by the three important castes, viz. Brahmins,

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[9] Ghurye, *Op. cit.*, p. 197; p. 179.

[10] Ghurye, *Op. cit.*, p. 179.

[11] *Administrative Report of the League of Non-Brahmin Youth*, Madras, 1926-27.

[12] The *Economic Weekly*, VI-39, 25th September 1954, pp. 1065 ff.

Mahratas and Mahars, in the politics of Maharashtra. The Brahmins were the first to become westernized in Maharashtra, and this resulted in a near monopoly of posts for them in the new set-up. The early political leaders were mostly Konkanastha Brahmins. The Brahmins constitute only 4% of the population of this region while the Mahratas constitute 25%, and the Kunbis who wish to pass off for Mahratas, 8%, and the Mahars, 10%. The Mahratas are landowners in the rural areas and have not yet taken kindly to education in spite of the pioneering efforts of their caste leader, the Maharaja of Kolhapur. They have only 7% literates as compared with the Untouchable Mahars who have 11% literates. The ties of the Mahars with the land do not seem to be as strong as those of the Mahratas—traditionally they were hereditary village watchmen owning little or no land. The Mahars, like the Mahratas, saw army service in the First World War, and large numbers of Mahars are to be found now in Bombay engaged as labourers in mills.

Miss Patterson tells us that in the twenties, Mahratas in Kolhapur, Satara and other towns made a concerted effort to drive out Brahmins from their position as priests, petty government officials and teachers. (It is interesting to note that a similar move was afoot in Madras Province. The leaders of the non-Brahmin movement in Madras were in touch with their counterparts in Belgaum, Satara and Amravati. (See *The Proceedings of the First Provincial Conference of the League of Non-Brahmin Youth (Central), Madras,* 1927.)

In Maharashtra as in Madras the Congress achieved a notable victory at the 1936-37 elections, and the non-Brahmin party candidates suffered a severe defeat. According to Miss Patterson, the Congress was able to attract Mahratas and other non-Brahmins into its fold partly because its leader Mahatma Gandhi was not a Brahmin. In her opinion, "all along in various ways caste has exerted an important though at times subtle effect on the Congress organization in Maharashtra."[13]

In April 1948, a large block of the Maharashtra Congress left it to form the Peasants' and Workers' Party. The leaders of the new party were Sri K. Jedhe and Sri S. S. More. Miss Patterson says "that the formation of this party may be regarded both as an attempt to protest against what was considered overtly 'Capitalist' domination of the Congress and to by-pass what was claimed to be continued Brahmin control over positions of leadership in the Maharashtra Congress organization."[14]

In 1954, the P. W. P. split into two groups, one led by Sri Jedhe, and the other by Sri More. The former rejoined the Congress in August 1954 while a hard core of leftists remained with Sri More in the P. W. P.

The agitation for a union of all Marathi-speaking areas including Bombay seemed to unite most Maharashtrians, irrespective of caste. There was, however, one notable exception: it was none other than Dr. B. R. Ambedkar, the leader of the Scheduled Castes. Dr. Ambedkar stated that "In a monolithic Maharashtra, Mahratas having the absolute majority would dominate." He added further that history had shown that the minorities, especially the Scheduled Castes and Tribes, would not get justice at the hands of the Mahratas. Dr. Ambedkar wanted Maharashtra to be divided into three Marathi-speaking areas, East, West and Central, with a view to seeing that the Mahratas did not get a chance to dominate the Scheduled Castes and Tribes.[15]

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[13] *Loc. cit.*, p. 1066.

[14] *Ibid*, p. 1067.

[15] *Times of India*, 1st October 1955.

VI

Mr. Selig S. Harrison, in a recent paper entitled "Caste and the Andhra Communists" in the *American Political Science Review* (vol. 1, no. 2, June 1956), has made a brilliant analysis of the forces at work in the politics of Andhra State. I make no apology for quoting extensively from Mr. Harrison's paper ; it provides conclusive evidence of the decisive role played by caste in the politics of South India, if not India as a whole. Mr. Harrison writes, "As an example of Hindu caste discipline in political motion, the post-war decade in Andhra merits special attention. *Caste has played so fundamental a role during this period that this examination becomes in effect a case history in the impact of caste on India's representative institutions.*" (p. 379. Italics mine.)

The time at my disposal permits me only to present very briefly Mr. Harrison's main points. According to Mr. Harrison, most of the Communist leaders of Andhra are Kammas. "Since the founding of the Andhra Communist Party in 1934, the party leadership has been the property of a single sub-caste, the Kamma landlords who dominate the Krishna-Godavari delta. This fact carries enormous importance in view of the rising influence of the Kammas in Andhra life. The War and post-War years were a boom period for the Kamma farmers, who own an estimated 80 per cent of the fertile delta land. High prices for both food and cash crops made many Indian peasant proprietor castes newly rich, but for the Kammas, presiding over land as productive as any in all India, the boom was especially potent" (p. 381).

While the Kammas dominate the Communist Party, the rival land-owning caste of Reddis dominate the Congress. Kamma-Reddi rivalry is an old affair and the present-day political competition between them "is only a modern recurrence of an historic pattern dating back to the fourteenth century." "Both Kammas and Reddis were probably warriors in the service of the early Andhra kings. Later they became farmers, some feudal overlords and others small peasant proprietors who to this day take part in the cultivation of their land. Between them they dominated rural Andhra leaving Brahmins beyond the pale of economic power in the countryside" (p. 382).

These two famous castes are concentrated in two different regions of Andhra—the Kammas in fertile deltaic Andhra and the Reddis in the five Rayalaseema Districts of West Andhra. (This kind of relationship between a caste and a region is widespread in India, and it should be noted that *regional claims are often only a disguise for caste claims*. The conferring of vast powers to panchayats, which is a widespread feature of modern Indian administration, will only place great temptations before the locally dominant caste, to use the money and power in favour of its members and at the expense of the other and dependent castes.) The deltaic region seems to have been called once upon a time 'Kamma Rashtra' while Rayalaseema is in parlance referred to as 'Reddiseema'. Both the castes are, however, rurally oriented. Political awareness in Andhra, as in other parts of peninsular India, came first to the Brahmin Like the Mahrata, the deep chthonic roots of the Kamma and Reddis seem to have come in the way of their acquiring English education. "Only about 1900 A.D. Kammas awakened to the fact that without English education they cannot better their position. The few educated Kammas who joined Government service had to struggle hard to come up due to lack of patronage and the opposition of Brahmin vested interests" (p. 384).

The educational advancement of the two castes only increased their mutual rivalry. But the two, however, combined as members of the Justice Party in Madras, to oust the Brahmins out of power and position in Andhra. Between 1934 and World War II, the Reddis gained control of Congress and the Kammas of the Communist Party.

I must mention here that I do not find Mr. Harrison's explanation for the two leading peasant castes joining rival political parties entirely convincing. According to him, the fertile and rich deltaic area of the Circars—incidentally the region of the heaviest density in Andhra, from 900 to 1,200 persons per square mile as compared with 316 in the rest of Andhra—is the centre of Andhra's intellectual and political ferment. The Brahmins in this area were the first to be drawn into the Congress and the challenge to the Brahmins came from the leading local non-Brahmin caste of Kammas. "In addition, in the delta's legions of landless labourers there was the grist of a mass movement plain to any Marxist intellectual looking for a cause" (p. 384). According to Mr. Harrison the Reddis who lived in the politically backward area of Rayalaseema, gravitated almost by default into the Congress.

This account of Mr. Harrison is not consistent with his earlier statement that "both Kammas and Reddis, pushing forward with the anti-Brahmin movement that swept all South India, supported the Andhra branch of the short-lived Justice Party" (p. 384). This statement implies that there was no lag between Kammas and Reddis in political consciousness. A simpler explanation and one that is more consistent with traditional Reddi-Kamma rivalry is that the two castes fell apart after pushing the Brahmin out. One joined the Communists and the other the Congress. The two rival castes now found a new field for their rivalry.

Between 1948 and 1951, communism in Andhra took a violent form. "This was the so-called Telengana movement, organised along standard Communist guerilla lines with wholesale land redistribution and parallel village governments. Clusters of villages in the delta and nearly all Warangal and Nalgonda districts in Hyderabad went under Communist control from 1948 to 1950. Andhra and Telengana Communist leaders directed a two-way offensive, north into Telengana and south into the delta, from a 40-village base of operations in Munagala Jungle in north-west Krishna District. Communist squads raided villages by night, police battalions by day. When Indian troops conducted their 1948 'police action' against the Nizam of Hyderabad, they stayed on in Warangal and Nalgonda to drive the Communists out. It took them until 1951 to restore normal local government" (p. 390).

Communist violence did not however effect the Kamma landlords and this was noticed by Sri B. T. Randive, then Secretary of the Communist Party of India. He said that the Andhra Communist Party was dominated by "rural intellectuals, sons of rich peasants and middle peasants." "The party politically based itself on the vacillating politics of the middle peasants and allowed itself to be influenced even by rich peasant ideology" (pp. 390-1).

The Kammas supported the Communists in the 1951 elections. "Whatever the understanding between the Communists and Kamma patriarchs, a significant section of the Kammas plainly put their funds, influence, and votes behind the Communist Kamma candidates. This factor appears to have tipped the scales in the delta. While the Kamma vote was divided, the share of Kamma support won by the Communists provided the margin of victory, in 14 of the 25 delta general constituencies where Communist deputies were elected" (p. 395). Mr. Harrison states that in a substantial number of cases powerful Kamma supporters gave even more decisive support to the Communist candidates, viz. that of identification with village-level authority. Kamma influence is so evenly spread over the delta that even in these deltaic constituencies where non-Kamma Communists were successful, Kamma support was probably extended.

In the 1955 elections, the Congress sent one of their ablest organizers, Sri S. K. Patil, to organize the Congress to defeat the Communists at the polls. The Andhra Congress closed its ranks and this minimized the splitting of votes among a number of candidates which was a feature of the 1951 elections. The Congress also secured the support of the outstanding Kamma leader, Prof. N. G. Ranga, and his support was a crucial factor in the defeat of the Communist candidates. Sri S. K. Patil matched caste with caste in the choice of candidates, and this ensured that the Communist candidate did not have the advantage of caste against his Congress rival. Finally, vigorous anti-Communist propaganda seemed to split the Kammas in their support of the Communists. The Communist press bitterly complained that the propertied interests had ganged up against them. On his side, Sri N. G. Ranga showed that he could drive a hard bargain for his caste within Congress councils.

What will be the pattern of forces in the new Andhra State? The *Times of India* of 25th August 1956 reported that there were two groups, one supporting the Chief Minister Sri B. Gopala Reddi, and the other supporting the Deputy Chief Minister, Sri N. Sanjiva Reddi, for the leadership of the Congress Legislative Party in the enlarged Andhra Pradesh. In this contest, the decision of the Telega subcaste (with 22 members in the Legislature) to support Sri Gopala Reddi strengthened the latter's chances of success. The followers of Sri N. G. Ranga also decided to support Sri Gopala Reddi. The Harijans were deliberating as to whom to support and it was likely that their vote would go to the highest bidder.

In Telengana, the leaders in the political field are the Reddis who are distinct from the Rayalaseema Reddis. The Telengana Brahmins are their local rivals.

A complicated pattern of alliances and rivalries is likely to emerge in the new Andhra. Writes Mr. Harrison, "already the Reddi-Brahmin rivals in Telengana and the Kamma-Reddi antagonists in Andhra can be seen each jockeying to establish ties across the border. To complicate matters still more, the Telengana Communist leadership lacks caste homogeneity. Ravi Narayana Reddi, and a Brahmin, D. V. Rao, lead rival factions. How will these rivals adjust to their new common relationship to the delta Communist leaders?" (pp. 403-4.)

VII

It is to be regretted that analyses of elections similar to Mr. Harrison's are not available for other parts of India. But some idea of the forces at work in the 1951-52 elections could be obtained even from newspaper reports. It is relevant to mention here that it is widely believed that the Congress Party in Madras is pursuing in the spheres of education and recruitment to services a policy which meets with support from the Dravida Kazhagam. In fact, as mentioned earlier, the success of the Congress in Madras is partly attributed to its pursuing a policy which makes a non-Brahmin party unnecessary. In an article entitled the "National Scene" in the *Times of India* of 12th July 1955, 'Darem' wrote, "But it is futile denying that a large majority of the people (which means the non-Brahmin majority) in Tamilnad sympathise with the Kazhagam's ideology. Indeed the present Chief Minister of Madras (Sri K. Kamaraj) owes his return to the Assembly to the support of the Kazhagam in the election. It is further believed that a majority of Congressmen actively back the Kazhagam."

During the elections the Communist Party of India, in accordance with its policy of supporting candidates and parties having a 'social base', supported the Dravida Kazhagam candidates. The Communists argued that though the Kazhagam was in origin a result of depressed non-Brahmins rising against Brahmin privilege, it had an economic and social basis and a 'progressive' or Leftist ideal. (See the *Times of India,* 2nd January 1952). In the same report, the *Times of India* correspondent remarked that the Scheduled Castes Federation was very powerful in Madras, and that the Harijans, constituted as they were of landless labourers and other impoverished sections of the community, were attracted to the extreme Left in thousands. The poorer Christians, mostly converts from Harijan castes, were also supporting the Communists, though in their case there was the counter-influence of the Church to the right.

The Vanniya Kula Kshatriyas are a dominant caste of petty landowners and poor peasants in the four districts of North Arcot, South Arcot, Salem and Chingleput. In the year 1944 this caste organized itself as a pressure group to promote its interests. But just before the elections, the caste split into two parties, one known as the Toiler's Party and the other as the Commonwealth Party. The former had Leftist leanings and was active in South Arcot and Salem, while the latter had no particular programme. The Toiler's Party was supported at the elections by both the Kisan Mazdoor Party and the United Front of Leftists. The *Times of India* correspondent remarked, "it is astonishing how much caste feeling is being evoked by the elections" (2nd January 1952).

VIII

I have already commented on the Dravida Kazhagam movement in Madras. Sometime in June this year, the founder of the Kazhagam, Sri E. V. Ramaswamy Naicker, declared that he had given up the goal of Dravidistan, a sovereign state consisting of Tamilnad, Kerala, Karnatak and Andhra, the four Dravidian-speaking areas of South India. He declared himself only in favour of Tamilnad, a tacit acknowledgement of the fact that the movement had never made any headway outside Tamil-speaking areas.

But the Dravida Munnetra Kazhagam, an offshoot of the Dravida Kazhagam, has not given up the demand for Dravidistan. A conference of the D. M. K. held in Trichy in the third week of May 1956, passed a resolution demanding the creation of Dravidistan instead of Dakshina Pradesh. (See the *Hindu,* 22nd May 1956.) The demand for Dravidistan as distinct from Dakshina Pradesh, is a demand for the creation of a sovereign and independent State. An acute controversy is raging at present between the advocates of Dakshina Pradesh led by Sri C. Rajagopalachari and the advocates of a Tamil State but this need not detain us here. But it is relevant to mention that in a recent speech Sri C. Rajagopalachari charged both the D. K. and D. M. K. of ". . . . openly preaching a creed of hatred based on ethnological conjectures and unrecorded and unproved historical conflicts." "It was claimed by these 'hatred-mongers' that the Dravidians were very strong and powerful and that the Aryans, who conquered them, were none else than the forbears of present-day Brahmins. This theory would not stand even half an hours examination." He asked, "Is it not remarkable that this hatred-mongering is going on meeting with little disapproval or discouragement from those in authority?" (See the *Hindu*, 16th June 1956).

IX

Caste is omnipresent in modern Mysore. As in Andhra, the Congress Party is dominated by two leading peasant castes, one of which is the Lingayat and the other, Okkaliga. Lingayat-Okkaliga rivalry is colouring every matter whether it be appointment to government posts or reservation of seats in colleges or election to local bodies and legislatures. A detailed account of the way in which caste functions in modern Mysore was given in the *Economic Weekly* of 21st July 1956.[16]

The Okkaligas of Mysore are apprehensive that in a large Kannada-speaking state composed of Mysore, Coorg and South-Canara, and the Kannada-speaking areas of Madras, Hyderabad and Bombay, they would be dominated by the Lingayats. This is why they wanted Mysore to remain a separate State. They continued to press for this even after the States Reorganization Commission had recommended the creation of a single State embracing all Kannada-speaking areas including Mysore. It was Sri Hanumanthiah's support for the S.R.C. proposal which changed the course of events. The supporters of separate Mysore even welcomed the creation of Dakshina Pradesh as a counter to a single Kannada-speaking State—in the former State no single group would be able to dominate. One of the dilemmas of modern India is that while smaller states will make for the more intimate association of the people with the Government, they are also likely to make for the tyranny of the dominant caste. *Devolution of power in India is seriously complicated by caste.*

That the members of the States Reorganization Commission were keenly aware of the apprehensions of the Okkaligas is evident in para 324 (p. 91 ch. IV) of their Report: "It has been suggested to us that the basic reason why two States have been demanded instead of one is either political or religious apprehension or perhaps a combination of both. It has been estimated that Lingayats or Veerasaivas constitute about 35 to 40% of the population in the Kannada areas outside Mysore at present. The other important section of the Kannadigas, namely, the Vakkaligas, similarly constitute a little less than 29% of the population of Mysore. In the united Karnataka, it has been estimated that a little more than 20% of the population may be Lingayats, between 13 and 14% Vakkaligas, about 17 to 18% Harijans. It is clear that no one community will, therefore, be dominant and any one section can be reduced to the status of a minority, if other groups combine against it. These estimates of the communal composition of the new State are naturally not firm, because the figures which have been quoted vary considerably.[17] They serve however to illustrate the problem."

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[16] See 'Profile of a Southern State—Mysore', *Economic Weekly*, vol. VIII, no. 29, pp. 859-865. See also the *Economic Weekly*, vol. VIII, no. 52, p. 943, and vol. VIII, no. 34, pp. 1005-6.

[17] According to the 1931 Census the percentage of Lingayats, Vakkaligas and Harijans in the areas proposed to be included in the Karnataka State was 17, 11, and 13 respectively.

Sri Hanumanthaiah's advocacy of the cause of a single Kannada State cost him the Chief Ministership of Mysore. His action has been interpreted as harming Okkaligas. With the approach of the formation of the new State, Okkaliga-Lingayat relations have become bitter. It is likely that in New Mysore besides a straightforward tussle between the two groups there will be regional conflicts. In fact, regionalism will be the pattern in India, south of the Vindhyas, if not all over India. This is an inevitable consequence of the formation of large states within the Indian Union. Regionalism is an offspring of linguism, and caste is active in either.

Another feature of modern Mysore is the recognition given to caste in appointments to government posts, seats in medical and engineering colleges etc. Brahmins may apply for only one in five posts, and only 30% of the seats in medical and engineering colleges are allotted on the basis of merit. (In Andhra, conditions seem to be worse, Brahmins being eligible to apply for only one in seven posts, and only 20% of the seats in colleges being open to competition.) It may be recalled in this connection that Article 29 (2) of the Constitution guaranteeing that "No citizen shall be denied admission into any educational institution maintained by the State or receiving aid out of State funds, on grounds only of religion, race, caste, language or any of them", was amended in 1951 to provide for reservation of seats in schools and colleges on the grounds of caste. The Constitution (First Amendment) Act was passed in 1951 and added the following to Article 15 of the Constitution. "(4) Nothing in this Article or Clause (2) of Article 29 shall prevent the State from making any special provision for the advancement of any socially and educationally backward classes of citizens or for the Scheduled Castes and Scheduled Tribes." The Amendment Act arose out of the case of Champakam Dorairajan vs the State of Madras. Miss Dorairajan, a Brahmin girl, was refused admission to a college in Madras, and she filed a writ petition. The Madras High Court held that the communal government order under which the action was taken was *ultra vires* of the Constitution. The Madras Government appealed to the Supreme Court which upheld the decision of the Madras High Court. Their Lordships of the Supreme Court declared that the classification made in the Madras Government order regarding admission to colleges proceeded on the basis of religion, race and caste, and was therefore opposed to the Constitution, and constituted a clear violation of the Fundamental Rights guaranteed to the citizens under Article 29 (2) of the Constitution and therefore void under Article 13. The Amendment to the Constitution was the result.

X

Kerala, or the Malayalam-speaking area, on the west coast of South India, differs in certain important respects from the rest of South India. For instance, it includes a large and influential Christian population, and in the northern part of the State, a well-knit group of Muslims. The Nambudri Brahmins of Kerala, who may be said to be Brahmins among Brahmins, have not taken to Western education in the way their Eastern and Northern counterparts have done. The Nayars are the important Hindu group in an educational, administrative and political sense. The Izhavans or Tiyyans, a 'backward' caste with the traditional occupation of toddy-tapping, have Sanskritized their way of life under the leadership of their revered leader, the late Sri Narayana Guru. Among Hindus, there is a certain amount of rivalry between the Nayars and Tiyyans, and in

Travancore-Cochin there is rivalry between Hindus and Christians. Kerala teaches us that it is not so much the ritual superiority of the Brahmin that is resented by the others, but his political and economic domination.

In the 1951 elections, the major cleavage in Travancore-Cochin was between Hindus and Christians. For a year before the elections the Democratic Congress carried on a steady and virulent campaign that the local Indian National Congress was dominated by Christians. This led to the exit of some Nayars and Tiyyans from the National Congress. Then came a sudden electoral alliance between the National Congress and Democratic Congress which confused many followers of the former. Many Izhavans turned left. The Christian vote did not go to the National Congress because the State Government tried to obtain control of tuition in schools which are mostly run by Christian missionaries. The Church resisted this attempt of the State and the Government of India reversed the decision of the State Government. The clergy and Catholic Congress supported Independent Catholics against the Congress nominees. Independent Catholics in Trichur called themselves the Cochin Party. When Hindus saw that the clergy were backing Catholic candidates, they voted against the Catholic nominees of the Congress and supported Hindu Independents and Leftists. The Congress vote was thus split. Five of eleven Independents elected to the Assembly were from Trichur.[18] A report in the *Times of India* of 27th August 1956 contained a revealing analysis of the forces at work in Travancore-Cochin State since its inception.

"For a long time Travancore and Cochin were two separate States ruled by two royal families and their advisors, called Dewans. In those days, it was not a sin to distribute favours. At least, the royal right was not challenged. The best available place to distribute favours was the expanding field of public administration.

"When self-rule replaced autocracy, it inherited the old machinery intact. But the units and components of this machinery were never seriously disturbed. In fact, some of the critics of ministerial rule in the State point out that the services enjoyed more opportunities for favouritism during the initial rise and temporary decline of representative government here.

"The Public, the newspapers and the people's representatives, all tended to identify and equate Government employees with this or that community. Appointments and promotions of clerks and sub-inspectors of police became front-page news and reacheed the agenda of Cabinet meetings. The failures and fortunes of Government employees were identified with the failures and fortunes of their respective communities. The employees enjoying rare privileges soon searched for and always succeeded in getting 'god-fathers', promoters and sponsors, among the leaders of public life."[19]

"In this small and compact area, every one knew every one else. Family connections and communal parity were much too important. Personal considerations and obligations held sway over efficiency and independence. Progress stopped. Inertia set in. This is the critical analysis of the recent history of the State Services by responsible officials.

"Into this stagnant pool flew the Presidential Agent, Mr. P. S. Rau. He detected the malaise. His writ that the Presideent's administration shall be strictly impartial ran through all departments. He felt that being a newcomer from beyond the State's borders he could do something in this direction. Mere seniority would not be the sole criterion for promotions, he said. Efficiency would be the keynote of the administration."

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[18] See the *Times of India*, 26th January 1952.

[19] Italics mine.

XI

I may be permitted to remark here that it is not unlikely that the absence of powerful Brahmin groups in the North has prevented the rising of an anti-Brahmin movement and this has probably led to the popular impression that caste is more powerful south of the Vindhyas than to the north. There are signs, however, that caste is becoming stronger in the North. Whether caste conflict will ever become as strong as it is in the South today, remains to be seen.

Strong caste rivalries were seen in the Bihar Congress during the 1951 elections. The three chief castes were the Rajputs (led by the Finance and Food Minister, Sri A. N. Sinha), the Bhumihar (led by the Chief Minister, Dr. Sri Kishna Sinha), and the Kayasth (led by Sri K. B. Sahay, Minister for Revenue and Excise). A *Times of India* report, dated 3rd January 1952, stated that many Congressmen were supporting surreptitiously, and in some cases even openly, many Independent candidates and disgruntled Congressmen standing against the Party's official nominees. In short, Rajputs supported Rajputs, and Bhumihars supported Bhumihars, occasionally in contravention of party loyalty. The Kayasths, however, were split into two groups, one of them supporting Sri A. N. Sinha.

While some Congressmen supported caste fellows at the expense of the Party nominees, some members of the party of Rajput landlords, the Janata Party (led by the Raja of Ramgarh), expressed their preference for Sri A. N. Sinha.

The Congress exploited the principle of caste in the elections. Rajkumari Amrit Kaur was brought to tour the tribal areas to wean away tribesmen, a good many of whom are Christians, from a separatist demand for a tribal State to be called Jharkhand. The leader of the Jharkhand Party, Sri Jaipal Singh, himself a Christian tribal, wanted a new state to be carved out of the tribal areas of Bihar, Madhya Pradesh and Orissa.

In 1951 there was in existence in U. P. an organization called the Shoshita Sangh, comprising of the lower castes, which had as its aim the improvement of the conditions of the latter.[20] This seems to be but one indication of the fact that caste-consciousness is on the rise in U. P. The tussle between the Rajputs and Chamars for political power is likely to get keener in the near future. In the rural areas the Rajputs, who were until recently an exclusive group, seem to be more willing nowadays to grant Rajput status to aspiring groups with a view to strengthening themselves at the next elections.

An incidental effect of the abolition of the zemindari system in parts of North India was the outbreak of dacoity in parts of U. P. and Madhya Bharat. The dacoit gangs in U. P. were recruited almost exclusively from among the Thakur, Mallah and Gujar castes which collaborated effectively to protect the criminals wherever they went. Punitive police were posted in the affected areas in December 1952—January 1953, by the U. P. Government. Similarly, in Madhya Bharat, the Rajputs, Thakurs and Gujars who were adversely affected by the post-Independence agrarian reforms took to dacoity. (See the *Times of India*, 26th Jan. 1953.). In the latter half of 1952, in certain villages in Bhind and Morena Districts of Madhya

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[20] *Times of India*, leader, 14th November 1951.

Bharat, Harijans were frequently victims of loot, arson and murder at the hands of the dacoits. These assaults were described by the *Times of India* correspondent as a kind of 'class war' waged by the Zamindars (who had suffered by the abolition of zamindari,) against the people (Harijans) whom they had oppressed formerly (See the *Times of India*, 25th November 1952).

XII

In the Punjab, the conflict is not between castes but between two systems of castes—the Hindu and Sikh. The Hindu-Sikh conflict took on the guise of a linguistic conflict and this was in spite of the fact that "the Punjabi and Hindi languages as spoken in the Punjab are akin to each other and are both well understood by all sections of the people of the State."[21] "The problem of language in the Punjab is, therefore, one of scripts . . . ."[22] The Sikhs wanted Gurmukhi script while the Hindus wanted the Devanagari script. The S. R. C. turned down both the Sikh demand for the creation of a Punjabi-speaking State as well as the Hindu demand for a Maha (bigger) Punjab State. They proposed the creation of a new Punjab in which was merged the existing States of the Punjab (except the Lohari sub-tehsil of Hissar District), PEPSU and Himachal Pradesh.[1] The Commission criticized Sikh as well as Hindu communalism and gave their support to a compromise plan: "As for the possible unfavourable repercussions of enlarging the present State of Punjab on the existing communal equilibrium, the position is that the proposal which we make about this region will no doubt result in the formation of a larger unit, but the Sikh percentage in the enlarged unit will not be adversely affected as compared with their percentage in the existing State of Punjab. The Sikh percentage in the proposed State will in fact show a small improvement of a little more than 1·5%, resulting in a corresponding decrease in the Hindu percentage."[23] It is ironical that the S. R. C. proposal makes an appeal to the same communal sentiments which it so loudly deprecates.

It was the Shiromani Akali Dal which sponsored the idea of Punjabi-speaking State. The reasons which prompted it to do so are not difficult to guess. In a recent speech, Sardar Gyan Singh Rarewala, formerly Chief Minister of PEPSU, stated that the Sikhs were suffering from frustation ever since Independence because of the denial of "due status to Punjabi language and Gurmukhi script", discrimination against Sikh Scheduled Castes, and discrimination against the Sikhs in Government service both in appointments as well as promotions. (See the *Hindu*, 11th June, 1956.).

The Congress Government have evolved a 'regional formula' to set at rest Sikh apprehensions of domination by Hindus. This solution has been opposed by the Hindus. The *Times of India* reported that at an emergency meeting of the Maha Punjab Samiti Working Committee held on 5th Sept. 1956, a resolution was passed declaring that the "unpatriotic regional formula for the Punjab was intolerable and would have to be resisted by measures sterner in nature than those adopted by the Samiti previously." (See the *Times of India*, 7th September 1956).

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[21] & [22] *Report of the States Reorganization Commission*, S. 520, p. 141, and and S. 527, p. 143.

[23] *Op. cit.*, S. 568 (p. 153); S. 550 (pp. 148-9).

XIII

I have nearly come to the end of my sketchy survey of the role which caste is playing in modern India. There is one important matter, however, to which I must make a reference, necessarily inadequate, before sitting down. Under the Constitution, the practice of Untouchability in any form is forbidden. Enforcement of any disability arising out of Untouchability shall be an offence punishable according to law (Article 17 of the Constitution). Articles 15, 25, 29 (2), 38 and 46 deal with both the positive and negative aspects of untouchability, i.e., preventing all forms of discrimination against any group of people as well as the adoption of positive measures to put an end to untouchability, and to help promote the educational and economic interests of the weaker sections of the people, and in particular, the Scheduled Castes and Scheduled Tribes.

The Constitution grants statutory protection to the Scheduled Castes and there are specific provisions which guarantee protection in various contexts. Thus there is a reservation of seats for Scheduled Castes in the Lok Sabha and in the State Legislative Assemblies. Out of 495 seats in the Lok Sabha, 72 seats have been reserved for Scheduled Castes. In the State Legislative Assemblies, against a total number of 3283 seats in all States, 477 seats have been reserved for Scheduled Castes.

The Constitution has also provided for the reservation of appointments for Scheduled Castes in the Services of the Union and State Governments. Under Article 35, the claims of the members of Scheduled Castes and Scheduled Tribes are taken into consideration, consistently with the maintenance of the efficiency of administration, in the making of appointments to services and posts in the Union and State Governments. 12½% of the vacancies filled by open competitive examinations in the Central and All-India Services are accordingly reserved for members of the Scheduled Castes. The reservation is increased to 16⅔% in the case of posts and services filled otherwise than by open competition on an all-India basis. Besides the above, the various State Governments have also made some efforts to improve the economic, educational and social conditions of Scheduled Castes. Some of them have resorted to legislation to give special protection to the Scheduled Castes.[24]

The conscience of modern Indians demands that untouchability be abolished and everything that is possible be done to bring the Scheduled Castes and Tribes and the various other groups subsumed under the blanket term of Backward Classes, to the level of the so-called advanced groups. But it is beginning to be increasingly realized that the measures devised to bring about social and economic equality might themeslves perpetuate the evil system of caste. In fact, this question was raised in a pointed manner by Pandit Pant in his concluding address to the Seminar on Casteism.[25] It is understandable that groups which are classed as 'backward' show reluctance to give up the privileges of 'backwardness'.

As I write these lines, a news item in the *Times of India* (5th September 1956) reports that the Government of India has found the report of Backward Classes Commission vague and inadequate as the latter have failed to establish objective and acceptable criteria for defining 'backwardness'. The Commission was appointed in 1953 under Article 340 of the Constitution with Kaka Kalekar as Chairman. Its terms of reference were to determine the criteria to be adopted in considering whether any sections of the people—in addition to those listed as Scheduled Castes and Tribes—should be treated as socially and educationally backward, to prepare a list of such classes, and to recommend ways and means of assisting them and improving their condition.

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[24] *Report of the Seminar on Casteism and Removal of Untouchability*, Bombay, 1955. See Sri Shankar Saran's address, pp. 95-104.

[25] *Op. cit.*, p. 152.

The Commission's list contains as many as 2399 communities of which 913 alone account for an estimated population of 116 millions while the Scheduled Castes and Tribes will make up another 70 millions. All women have been regarded as backward, though they are not listed among the Backward Classes since they cannot be regarded as a separate community.

According to the Commission, then, about three-fourths of the country's population would be 'backward'. It is difficult to see how special privileges could be given to such a large section of the population, and this is clearly recognized in the Government's Memorandum on the Commission's Report.

A majority of the members of the Commission were of the opinion that caste determined the degree and extent of backwardness. The Government of India did not accept this view, but it admitted that the caste system is the greatest hindrance to progress towards an egalatarian society. It added the warning that the recognition of the specified castes as backward may serve to maintain and even perpetuate the existing distinctions on the basis of caste.

The Government's position is understandable and it is high time thought was given to evolving 'neutral' indices of backwardness, indices which also include the Scheduled Tribes and Castes. The criteria of literacy, landownership and income in cash or grain, should be able to subsume all cases of backwardness. This is admittedly a huge and difficult task but not impossible. And the end may make it worth while.

XIV

One last point. Caste is so tacitly and so completely accepted by all, including those who are most vocal in condemning it, that it is everywhere the unit of social action. Some caste conferences have been urged by their leaders "to seize the opportunities afforded under the Five Year Plan to the fullest advantage and contribute their share to the industrial development (of the country)." (Silver Jubilee of the Nadar Mahajana Sangam at Virudhunagar. See the *Hindu*, 29th May 1956). Sri S. Chenniah, President of the Mysore Pradesh Congress Committee, was giving expression to a widespread sentiment when he stated in an address to the conference of a particular caste in Nanjanagud in October 1955, that "Communal bodies striving for economic and social uplift cannot be dubbed as harmful. Human psychology being what it is, it often was the communal bond which urged them to action." He expressed his pleasure at his having won the confidence of the members of the caste in question. He pointed out that the hostel which had been built for students of this caste had now been thrown open to students of all castes. He held out the assurance that when candidates were selected for the next general election the claims of the members of this caste would receive due attention. But even Chenniah argued that there must be a limit to caste organizations.

Commenting on the above Report, the *Times of India* remarked in a leader (23rd October 1955) that, "The politician who wants caste and communal distinctions should disappear is at the same time aware of its vote-catching power, and is thus faced with a real dilemma. Where should he draw the line when he is asked to extend help and patronage to communal organizations? Should a Union Minister grace by his presence a function arranged by a sub-caste among Marathas? Could a newly-elected Congress President allow himself to be garlanded by caste fraternities?" The leader concluded by saying, "The first step towards solving the dilemma facing the politician is to recognize its (caste's) widespread incidence and implications." It is however, only the first step. It is high time that everyone recognized that caste is an unmitigated evil and any truck with it is to be discouraged. To those who would think of using caste to achieve good I would say that that is the way caste is using good people to perpetuate itself. Means are as important as ends.

SECTION OF MEDICAL AND VETERINARY SCIENCES

President :—C. R. Das Gupta, M.B., D.T.M., F.N.I.

PRESIDENTIAL ADDRESS

CONTENTS

1. Introduction.
2. A brief resume of some Research Institutions in India—
    - (i) Haffkine Institute, Bombay.
    - (ii) The Central Research Institute, Kasauli.
    - (iii) Malaria Institute of India, New Delhi.
    - (iv) Nutrition Research Laboratories, Coonoor.
    - (v) School of Tropical Medicine, Calcutta.
    - (vi) All India Institute of Hygiene and Public Health, Calcutta.
3. Medical Research sponsored by Indian Council of Medical Research.
4. Research in Medical Colleges.
5. Brief note on the trend on medical research in India.
6. Essential pre-requisites for research—
    - (i) Personnel—Training : Employment.
    - (ii) Equipment.
    - (iii) Animals.
    - (iv) Journals.
    - (v) Library.
    - (vi) Co-ordination.
    - (vii) Funds.
7. Recommendations.

MEDICAL RESEARCH IN INDIA

I

Introduction

In the past medical research was confined to the study of the pathological conditions in man. From the study of disease the medical research today is moving forward to the study of health, and the recent trend in medical research includes study in Social, Economic and Environmental factors influencing the pathological condition in man. Role of genetics in health and disease is slowly being recognised and the time is not far off when more emphasis would be given to research on this aspect not only by Biologists, as is being done now, but by Medical people as well.

Before the present century Medical Research in India was sporadic in nature and was wholly due to the zeal and enthusiasm of some European Medical Officers who carried out valuable research with the very limited resources and inadequate laboratory facilities at their disposal. Works of outstanding importance were carried out by Lewis on Trypanosomiasis and Filaria ; Vandyke Carter on Spirilla and Leprosy ; Macnamara on Cholera ; Frayer on Snake venom ; Haffkine on Cholera and Plague while the epoch making discovery of Malaria was made by Ross in a little room attached to the Presidency General Hospital (now Sukhlal Karnani Memorial Hospital).

Organised medical research may be said to date from the beginning of the present century when a number of institutes viz. Haffkine Institute, Bombay (1896) ; Pasteur Institute, Kasauli (1900) ; Central Research Laboratory. Kasauli (1906) ; The King Institute of Preventive Medicine, Madras (1903) ; Pasteur Institute, Coonoor (1907) ; Malaria Institute of India (previously known as Central Malaria Bureau, Kasauli), New Delhi, (1909) ; Pasteur Institute, Shillong (1917) were established. An impetus to research was given by the creation of Indian Research Fund Association in 1911. Schemes for extended activities were, however, cut short by the outbreak of war.

A number of important Research Institutions were established in the post-war period. These are: Nutrition Research Laboratories (1918) ; School of Tropical Medicine (1920) ; All-India Institute of Hygiene and Public Health (1932) ; Indian Institute for Medical Sciences, the first non-official medical research institute in India (1935) ; Bio-chemical Standardisation Laboratory, now called the Central Drugs Laboratory (1937) ; Central Research Institute, Trivandrum (1939) and the Tata Memorial Hospital, now called the Cancer Research Institute, Bombay (1943). In 1927 the Central Malaria Bureau was expanded and named Malaria Survey of India which title was again changed to Malaria Institute of India in 1938.

Establishment of National Institutes in different parts of India and upgrading of some departments in the different Medical Colleges has also helped to foster research. The beginning of the second five year plan has been ushered in with the establishment of the All-India Institute of Medical Sciences in Delhi and the taking over the Indian Institute for Medical Research by the Council of Scientific and Industrial Research under the new name Indian Institute for Bio-Chemistry and Experimental Medicine. The Tata Memorial Hospital was taken over by the Government which is now called Cancer Research Institute. It is thus seen that steps are being taken, though slowly, for development of Medical Research in India.

2

A BRIEF RESUME OF SOME RESEARCH INSTITUTIONS IN INDIA

(i) *Haffkine Institute, Bombay (1896).*

The Institute, the oldest in India, was established to fight out the outbreak of plague and was then known as the Plague Research Laboratory. The name was changed to Bombay Bacteriological Laboratory in 1906 and to commemorate the name of its founder it was re-named Haffkine Institute. At present the Institute has 9 major departments viz. Vaccine ; Antitoxin and sera ; Pharmacology ; Biochemistry ; Chemotherapy Entomology ; Experimental Pathology ; Clinical Pathology and Virus diseases including Rabies. There is also a Blood Bank department. An Assistant Director is in charge of each of the departments. The Institute is exceptionally well equipped and has as many as 5 constant-temperature rooms besides airconditioned rooms for the Blood Bank. Accommodation in the Institute is ample and has also excellent animal houses. The Staff are in the employ of the employ of the Government of Bombay ; service conditions are reasonably good but the pay scale is below the present day standard. The Institute serves as a training centre for Medical and Public Health Officers and Sanitary Inspectors for anti-plague measures. Activities of the Institute have increased considerably in the manufacture of vaccines, sera, anti-toxins, drugs and vitamins so much so that not only the whole of the budgetted expenditure is met from the sale of its various products but some money is also available for its expansion and development from the same source. As a result research is gradually receding to the background. The Institute which was established for research and had produced excellent work must be freed from its routine diagnostic and manufacturing activities and its resources must be harnessed in the furtherance of research. There are not many well-equipped research Institutes in India and it will be a pity if such an Institute is allowed to fritter away its energy in the manufacture of vaccines, drugs etc. Dr. Viswanath and Bhutt in their note on Medical Research rightly observed that 'apart from paucity of funds the worst enemy of the progress of medical research in India has been the fact that officers employed in the Medical Research Department were mostly engaged in the manufacture of biological products and had very little, if any, time to devote to their declared function—Medical Research'.

(ii) *The Central Research Institute, Kasauli* (*1906*).

This Institute was established as a central organisation for research in India. At Kasauli, the climatic condition is suitable for work at high pressure throughout the year. The equipments in the Institute are quite satisfactory, and it has an excellent library and good animal house. The Institute was originally meant for research both in the laboratory and in the field and used to give organised bacteriological courses at one time. The Institute is financed by the Central Government and is under the control of the Director-General of Health Services. The Institute is now mainly engaged in the large scale manufacture of vaccines, testing of disinfectants, and laboratory diagnostic work so much so that in the opinion of the Bhore Committee, the ever increasing demand for vaccines and sera manufactured at the Institute and other routine duties have progressively reduced the time available for research and since the last war have reduced research activities to a very low level.

(iii) *Malaria Institute of India, New Delhi* (*1909*).

For concerted study in malaria a Central Malaria Bureau was founded at Kasauli in 1909, and the Malaria Bureau was expanded into the Malaria Survey of India in 1927 under the auspices of the IRFA. The title was changed to Malaria Institute of India in 1938, and is now directly under the management of the Central Government.

The functions of the Institute are (i) Teaching—to train Medical officers, Engineers and others in malaria control work ; (ii) Research—to carry out research on malaria with an emphasis on control of malaria ; and (iii) Advisory—to advise Government on all matters relating to malaria.

The need for training personnel for control of malaria was realised as early as 1910. Since then a very large number of Medical Officers, Engineers and Inspectors have been trained by the Institute. Training to a very large number of people from different parts of India have helped to implement successfully the National Malaria Control Programme launched in 1953, the largest of its kind in the world on account of its huge dimensions and financed jointly by U.S.A., Government of India and the State Governments. Incidence of malaria has been considerably minimised in the Units where control organisations have been set up. It is expected that after the establishment of all the Units prevalence of malaria would be reduced to a negligible minimum as a result of which the mortality rate would be low and the morbidity rate insignificant so that it will no longer interfere with the social and economic life of the people. Though immediate effects have been exceptionally good a keen and constant watch shall have to be maintained and the programme continued for some years to come if permanent eradication is desired.

A Filaria Unit was added to the Institute in 1952. Since then the Institute is training personnel in the prevention of Filariasis. The Institute has also been entrusted with the National Filaria Control Programme.

(iv) *Nutrition Research Laboratory, Coonoor (1918).*

Established in 1918 under the aegis of IRFA and housed in the Pasteur Institute, Coonoor, the Nutritional Research Laboratory was established on a semi-permanent basis in 1925 and is now a fixed charge on the ICMR.

The main functions of the laboratory are to conduct research on nutrition, to hold annual courses in nutrition and to act as an advisory body on all questions on nutrition. The laboratory maintains a nutrition museum which attracts many visitors. The laboratories have carried out and are still carrying out work on nutritive value of Indian foodstuff. This is one of the few institutions in India where research is the primary concern. It suffers from disadvantage namely want of suitable cases for studies. It is expected that this deficiency will be obviated when the institute is transferred to its new location in Hyderabad. Though the institute has carried out extensive work on Indian foodstuff, this knowledge is not known even to the educated people. Knowledge which is not disseminated to the masses has little value and steps must be taken to bring the knowledge to the doors of the common man.

(v) *The School of Tropical Medicine, Calcutta* (1920).

The School with its attached small but well designed hospital, the Carmichael Hospital for Tropical Diseases, is a rare combination of a research institution and a hospital. In the words of the Bhore Committee 'The School of Tropical Medicine provides one of the few examples in India where advanced teaching and research are carried side by side, where advantage is taken of the excellent clinical material available and where students are trained in an atmosphere of research work.' The research work undertaken by the School embraces a variety of subjects which are peculiar to or are important problems in India and includes research in Bacteriology; Bio-chemistry; Chemistry; Clinical Pathology; Dermatology; Entomology; Filariasis; Helminthology; Haematology; Kala-azar; Leprosy; Pharmacology; Protozoology; Radiology and Tropical Medicine. Each of the subjects enumerated above enjoys the status of a separate department and is under the charge either of a Professor or a Research Worker. I do not agree with the view expressed by the Bhore Committee that 'this has the disadvantage from the point of view of training of young graduates' or that 'research work on narrow specialities is liable to be carried out in water-tight compartments' and that 'it would probably be more satisfactory if research work was co-ordinated after several of the departments have been amalgamated'. On the contrary, I strongly feel that the world-wide reputation earned by the School owes largely to its policy of de-centralisation. This policy of de-centralisation is being rightly followed by the All India Institute of Hygiene and Public Health, Calcutta.

There is extreme lack of accommodation in the School. The Bhore Committee have rightly pointed out that 'the various departments are so overcrowded that their research activities are impeded' and that 'training facilities of an extremely suitable nature are denied to many potential teachers and research workers.' The only remedy lies in its expansion. Though another floor has been added to the Hospital to accommodate a larger number of patients, it is regretable that nothing has been done as yet for expansion of the School. The School has a good library, probably one of the best in India, is fairly well equipped but lacks in a well designed modern animal house, so very essential for research.

Two regular courses of instructions are given : one of nine months' duration—D.T.M. & H. of the Calcutta University confined to medical graduates only (previously this was of six months' duration under the Faculty of Tropical Medicine where a few non-graduates were also admitted) ; the other is of three months' duration—L.T.M. under the Faculty of Tropical Medicine meant for licentiates. The School also admits qualified persons from all over the country and abroad for specialised study or research in any particular subject. Three courses, each of two weeks' duration, are given for the post-graduate study of Leprosy by the staff of the Leprosy Department. In addition, lectures and demonstrations are given by the members of the staff to the students attending the D.P.H., D.M.C.W., D.N., D.I.H. courses of studies at the All India Institute of Hygiene & Public Health. During the war the School organised special courses of instructions in Tropical Medicine for specialists in medicine of the British and American army.

Some departments of the School are staffed and maintained by the State Government while others are maintained by public donation, the Endowment Fund of the School. The ICMR pays for 2 professors at the School, maintains two Units, the Haematological Unit, and the Clinical Research Unit and finances a number of enquiries. The School is managed by a Governing Body which now though autonomous by constitution, is wholly subservient to the dictates of the State Government and the Governing Body now enjoys the status of a recommending body. There has always been differentiation between the staff maintained by the Government who are designated as Profssors though some of them have very little teaching duties and the Staff maintained by the Endowment Fund who are called Research Workers though many of them have good amount of teaching duties. Many of the Departments are understaffed and there is no provision for an Associate Professor or Understudy in any of the departments. The pay scale of the workers is much lower than in other government institutions while the emoluments of the workers under the Endowment Fund are even lower than the government employees of the School. The service conditions of the Endowment Fund workers have not been clearly defined in all these long years and of late, under the new autonomous Governing Body, the service conditions of all categories of workers, particularly of the senior workers are worse off than before. Toeing with the retrograde policy of the State Government all Senior appointments are now on a contract basis for *five* years and pension, which was so long enjoyed by the government employees, being out of question. Further, all new appointments are now made by special Committees, the composition of which is not always beyond criticism, and not by Public Service Commission, as was the practice before.

Research activities of the School have been very extensive and of a varied nature though much of the work done has a clinical bearing. The School has already made valuable contributions in a variety of subjects in some of which its work has been of a pioneering nature. I fully agree with the views expressed by the Bhore Committee that 'given suitable opportunity to expand the School will develop into a centre for teaching and research in Tropical medicine second to none in the world'. But as an essential prerequisite to this the School must have contented workers with adequate pay, security of service and without any distinction between the different categories of workers. It is the paramount duty of the State Government to implement these but if they are not inclined to do so, it should be taken over by the Central Government, for, the School for all practical purpose is an All-India Institution and must be maintained on an All-India basis. Unless this is done, the School may lose its speciality as a 'fine research and post-graduate teaching centre' like other State Government managed institutions of the country.

(vi) *The All India Institute of Hygiene & Public Health, Calcutta (1932).*

The All India Institute of Hygiene & Public Health with its rural health centre at Singur (established in collaboration with the Government of West Bengal) and the Urban Health Centre at Chetla (established in collaboration with Calcutta Corporation with financial help from the WHO and UNICEF for applying knowledge of medical protection to large community groups) is the first of its kind in Asia.

The Institute was organised on the lines of John Hopkin's School of Public Health in U.S.A. to provide trained Public Health Personnel and to serve as a Research centre. The Institute started with 5 sections and by 1950 had the following 8 sections—Bio-chemistry and Nutrition; Epidemiology; Maternity and Child Welfare; Microbiology; Physiological and Industrial Hygiene; Public Health Administration and Statistics. Again in 1951 as a joint programme between the UNICEF and the Government of India another floor was added to the existing building and all the sections, particularly the section of Maternity and Child Welfare were expanded to serve as an International Training Centre for Maternity and Child Welfare Workers of South East Asian Countries. The policy of the Institute has been one of de-centralisation and not of amalgamation, a right step for further progress and development.

Accommodation in the Institute is quite adequate for its present needs. It is well equipped and has a good library. The libraries at the Institute and at the School of Tropical Medicine serve as complementary to each other.

The Institute offers courses of studies in 21 different categories; 10 for degrees and diplomas and 11 for certificates. The number courses of studies undertaken are too many as a result of which research activity is suffering. Unless steps are taken to relieve the staff of their ever increasing teaching duties, the Institute may be converted into a mechanical post-graduate teaching institution without much research activity which is so very essential for healthy development of any teaching institution, under-graduate or post-graduate. It may not be out of place to mention here that appointment of Foreign Consultants, particularly in the cases where Consultants are available in India, should be discouraged, more so as Indian Consultants would be better conversant with local conditions. The Foreign Consultants may however be invited for short periods for discussion with the local Consultants.

The Institute is under the direct management of the Central Government. The institute is adequately staffed and each department is under the charge of a Professor who is assisted by one or more Assistant Professors and a number of Demonstrators ; many of the Departments have also an Associate Professor, who is virtually an understudy to the Professor. This is a move in the right direction and should be emulated by other institutions. The staff are wholetime workers, better paid than the staff in many other research institutions, and have security of service. Besides the permanent staff there are a number of workers employed by the ICMR on a year to year basis.

Significant contribution to medical research has been made by other Institutes enumerated before, want of space does not permit a detailed description of their activities. It should, however, be mentioned that the ever increasing diagnostic and manufacturing duties in some of these institutions have put their research activities in the background. There are not many research institutes in the country and unless steps are taken to free them from their routine duties, progress of research is sure to suffer.

3

RESEARCH SPONSORED BY INDIAN COUNCIL OF MEDICAL RESEARCH

A significant and important landmark in medical research was the creation of Indian Research Fund Association in 1911 by the government of India as a local fund not administered by the government of India. The name I.R.F.A. was changed to Indian Council of Medical Research in 1950.

The I.C.M.R. was virtually constituted on the lines recommended by the Bhore Committee but the progress made in all these long years has not been up to expectation. Though this was mainly due to lack of adequate funds, paucity of trained workers and want of suitable equipments, policy followed by it was responsible, at least to a certain degree, for the unsatisfactory progress in research. In the past greater portion of the funds was spent on investigation into the major epidemic and endemic diseases of India and on malnutrition and to a much lesser degree on clinical and even much less on basic research. This policy has now been entirely changed and clinical research now claims about 50 per cent of the budgetted amount. It has also been the practice in the past to finance disjointed schemes by individual workers. In 1953 the Advisory Committees were requested to review the progress in their fields of activities and in 1954 they were requested to formulate precise schemes of work to bridge over the gaps in existing knowledge with particular emphasis on the needs of the country. Some of the Advisory Committees held special meetings and recommended some definite schemes for inclusion in the Second Five-Year Plan.

Funds :

This organisation is entirely dependent on the Central Government for its funds. In 1950-51 it was agreed by the Standing Finance Committee of the Government that a sum of Rs. 12 lacs would be treated as annual standing charge and that additional grants should be available for projects approved by them. In the memorandum on the development of Medical Research in the Second Five-Year Plan, the Secretary (present designation the Director) in an analysis of the budget for the year 1954-55 pleaded for the increase of the annual grant of Rs. 12 lacs to Rs. 25 lacs, Rs. 13 lacs for fixed charges and units and Rs. 12 lacs for development of its research programme. Such a development is considered not only necessary but imperative. But at the same time it cannot be denied that there is great room for improvement particularly in formulating research schemes and policy. As pointed out already until a few years ago grants for research were given for disjointed schemes by individual workers for many of which not even comprehensive reports were available at the conclusion of the enquiry. This was usually due to lapse on the part of the investigators who work absolutely in an honorary capacity and the I.C.M.R. had not the slightest control over them so far as the carrying out of the schemes under the I.C.M.R. is concerned. The changed policy of the I.C.M.R. will help to canalise research in a co-ordinated basis but ways and means shall have to be evolved for having some sort of control over all investigators receiving help from the I.C.M.R. and to have periodical check on the progress of their work. This work should be entrusted to Special Officers specifically employed for this purpose. And considering the vastness of the country four such officers should be employed on a zonal basis at least as a trial. For, any amount of Government grant would not help to solve the various problems unless the fund at its disposal is carefully nursed and allocation made according to various country-wide problems, which must be judged dispassionately.

Employment of research personnel:

The Director recommends the creation of 100 posts in the research cadre, 60 in the Junior cadre, 30 in the Senior cadre and 10 in the Selected cadre with a pay structure of Rs. 600-900 for Junior cadre Rs. 800-1,200 for Senior cadre and Rs. 1,000-1,500 for the Selected cadre with a non-practising allowance of Rs. 400/- which is equivalent to the recommended pay scale of the teachers of the Medical Colleges by the Central Health Council. The Council further proposes that the research cadre must be sufficiently broad-based and comprise of representatives of all fields of medical science, should be flexible to allow of continual absorption of new aspirants, should be permitted by the Universities to act as guides or supervisors for post-graduate students and, where possible, should have some teaching duties. The teachers on the other hand must undertake some research work so that the two cadres, research and teaching, could serve as complementary to each other. The Council further suggests that present workers of the Council, if found suitable, should be absorbed in the cadres and provision should be made for 26 posts, 16 in the Junior, 7 in the Senior and 3 in the Selected grade during the Second Five-Year Plan.

It is regretable that the Council has not made any recommendation about the existing personnel. The existing personnel under the I.C.M.R. in the different units, enquiries etc. form the backbone of the research organisation of the I.C.M.R. All of them are employed on a year to year basis, which practice must be stopped forthwith and the deserving candidates after thorough evaluation of their experience, aptitude etc. must be employed on a permanent basis. Mere opening up of the different cadres of research workers would not help to implement any research programme for which trained and contented workers in the lower scale are also essential.

The Council in their recommendation has not mentioned whether employment in the different cadres of medical research will carry a pension or not. This is important. For, an individual after spending the better part of his life in research would be at deep sea after superannuation unless some provision is made for his old age, as it is not possible for him to take up clinical work like his counterpart in the teaching line. Another important omission in this recommendation is non-mention of the age of superannuation. It is a well known fact that at the present day the policy followed by the different institutions is not at all uniform and in many instances active people with brilliant research record are thrown out at the end of 55 years, though it is admitted by everybody that there is great paucity of trained personnel. One fails to understand that if politicians without any previous training could work, even after 70 years, how is it that research workers with many years of training should be asked to quit, even when there is a great dearth of trained research workers, to satisfy the likes or dislikes of the politicians, who are usually the superior controlling authority both in the state and in the centre. This must be stopped and the research workers should be allowed to work up to 60 years and more as under the C.S.I.R. and provision should be made for old age.

Fellowship Programme :

As already pointed out the Fellowship programme started in 1945 and continued upto 1950 did not yield the desired result though a sum of about Rs. 2 lacs was spent per year. The Council in collaboration with the Rockefeller Foundation has reoriented its fellowship programme with the following objectives :—

(i) To train teachers and research workers for medical colleges.

(ii) To aid the development of certain departments in medical colleges for post-graduate training centres.

(iii) To improve the value of and the respect for Indian medical qualification as foreign post-graduate degrees or diploma or training abroad under totally different conditions are not considered the best preparation for a medical or scientific career in India.

This programme has already produced encouraging results. If the scheme is followed in the right spirit without any bias or prejudice and is under the control of an efficient person with ample research experience and at least some teaching experience the programme should meet with better success than its predecessor.

Scientific Advisory Board, Advisory Committees etc. :

Though the I.C.M.R. is constituted on almost similar lines as recommended by the Bhore Committee but the spirit underlying the recommendations have not always been followed. In the S.A.B. there is no representation of the University, of the Principal Scientific Bodies or of the Fundamental Sciences. Steps should be taken to include them, if required, even by increasing the number of members in the S.A.B., while the rule of automatic retirement after 3 years should be followed both in letter and in spirit.

The different Advisory Committees and Sub-Committees were reoriented in 1955, there being 11 Advisory Committees and 14 Sub-

Committees in 1955-56. This was reported to have been done with an eye to the present needs of the country. But this contention of the Council is difficult to follow when it is noticed that important subjects like Filaria, Leprosy, Malaria and Tuberculosis for which country-wide National Programme are being envisaged and most of which were under Advisory Committees before have now, under the new policy, been relegated to Sub-Committees. The Advisory Committees and the Sub-Committees are expected to be composed of experts on the different subjects. But a perusal of the composition of these would show the names of a few in 3 or more committees or Sub-committees though some of these may not be allied subjects. This procedure may be economical but not certainly to the best interest of research. Unless steps are taken early to run the organisation in an efficient way the apprehension expressed by Drs. Viswanath and Bhutt in their note in the Bhore Committee's report *viz.*, 'The argument of less red-tape in the working of a quasi-government organisation is offset by greater scope for nepotism under such organisation' may come true.

Further development of medical research in India:

In the Bulletin on medical research in the Second Five Year Plan need for the establishment of centre for training in Biological sciences and provision for animals for research has been rightly stressed, but the same cannot be said for the scheme for the establishment of a Blood Group Reference Centre in Bombay. This contention is supported by the low incidence of Rh negative cases and still lower incidence of cases of erythroblastosis foetalis in Bombay as will be seen in the note on Rh factor and its importance in erythroblastosis foetalis in Bombay. On the other hand it has failed to emphasise the need for establishment of more Haematological units in the country, which was recommended by the Haematological sub-committee and endorsed by the S.A.B. in 1955. There cannot be any justification in the opening up a Blood Group Reference Centre the need for which is rather limited and not recommending the establishment of a chain of Haematological Units, the need for which is both great and urgent. With the development of Haematological Units, blood group centres are sure to be developed, the latter being a component part of the former.

The I.C.M.R. is the only one organisation created for Medical Research in India. I feel I am justified in discussing the working of the organisation in some detail. Though it is entirely dependent on the Government for its funds, it is an independent organisation as was meant to function without red-tapism. Contribution of I.C.M.R. in the progress of medical research in recent years in the country is not mean and one still looks forward to it for further guidance and help.

Medical research was also sponsored, directly or indirectly by Social Welfare Organisations *viz.*, Hind Kusth Nivaran Sangh (formerly B.E.L.R.A.) and King George Thanksgiving (anti-tuberculosis) Fund ; Commercial Firms *viz.*, Tatas and International Organisations *viz.*, Rockefeller Foundation, World Health Organisation, Technical Co-operation Mission and others. Training of personnel has been helped by grant of Fellowships by Associations, Organisations and Firms, both Indian and Foreign. In this connection one cannot but deprecate the policy followed by the Tatas in the award of their Senior Fellowship for leukaemia ; a more nationalistic outlook would be desirable.

4

RESEARCH IN MEDICAL COLLEGES

Research is regarded as one of the normal functions of the medical institutions in Western countries funds for which are made available by grants and/or endowments from private or public sources. This is however not the case in the medical institutions in India. According to Prof. A. V. Hill, Secretary of the Royal Society, research was almost non-existent in medical colleges in India. The same view was also expressed by most of the witnesses before the Bhore Committee. As a result of which medical students in this country have to complete their studies without coming in contact with any planned scientific investigation, a very serious deficiency in the method of their training. Lack of interest for research in medical colleges in India is attributed to a complicity of factors by the Bhore Committee the more important of which are :

(i) Ignorance on the part of the authorities concerned of the value of research in relation to teaching.
(ii) Understaffing.
(iii) Low pay scale and thereby compelling the teachers to indulge in private practice.

Lack of accommodation, want of equipment and above all want of initiative on the part of the teachers are other important causes. From an analysis of the research activities in medical colleges the Bhore Committee were of opinion that the output of research varied with the energy and enthusiasm of individual workers ; all other factors were of secondary importance. One cannot but agree with the view point expressed by the Bhore Committee knowing as we do of the brilliant research work carried out by Rogers, Brahmachari and Rao and a number of other workers under very trying circumstances. I shall be failing in my duties if I do not mention here the genuine desire for research on the part of some of the present day college teachers inspite of innumerable difficulties, their number though few is not absolutely non-existent. This desire for research is noticed more in non-clinical departments than in clinical departments for obvious reasons. The attitude of the Government in medical institutions can better be described in the words of a witness before the Bhore Committee, who remarked 'Research has never been an active interest of Government organisations and facilities for it had to be slowly wrung out of unwilling administrators. Schemes for advancement of learning and research are usually shelved under the plea of financial stringency, unless the authorities are stimulated into action by such major catastrophies as wars or epidemics'. Though conditions are now slowly changing for the better, one would never expect to get the desired result unless drastic actions are taken to reorganise the medical institutions on the lines of the Western countries where research forms an integral duty of teachers. The teachers must be whole-time workers and adequately paid, provision must be made for instruments, accommodation etc. and the teachers must not be burdened with excessive teaching duties. Admission of students in two shifts, as was done in some of the Calcutta Colleges recently without proportionate increase in staff, equipment or accommodation cannot but be condemned. There is no possibility of producing good basic doctors badly needed by millions of peoples in India unless research is co-ordinated with teaching.

Funds must be provided for by the Government out of their own funds and should be supplemented by donations from the public and the commercial firms and business associations. If the School of Tropical Medicine could be established in the pre-independence days with donations and endowments from the public and commercial firms there is no reason why funds for research in medical institutions could not be obtained now, after we have attained Swaraj, if of course, a drive is made in the right direction.

The conditions in the non-Government institutions whose numbers are not few are still worse off. They are usually staffed with honorary part-time workers and lack even in ordinary equipments. Here also, initiative and genuine desire to carry out research may be noted on the part of an occasional worker which seldom, if ever, fulfilled on account of difficulties enumerated above. These institutions, if allowed to function, must be subsidised by the Government and brought in line with the Government institutions. If feel that by simply upgrading the medical Schools into colleges, as has been done and is being done in most parts of India, would not help to produce the 'basic' doctors unless research is integrated in the teaching institutions.

The recently changed policy of the I.C.M.R. in holding its annual meetings in the newly established medical colleges in different parts of the country and of inviting the Principals of medical colleges to attend the meetings are moves in the right direction. These have helped to make the staff of the medical college research conscious and stimulate research activity in them. The new fellowship programme of the I.C.M.R. in giving adequate training to the young employees of medical colleges is another move in the right direction, if of course it is done in the right way without any bias or prejudice. The I.C.M.R. might also help in the initiation of research in medical colleges by meeting the pay of a few suitable Professors in the different medical colleges, as is being done in the case of School of Tropical Medicine, on the condition that such Professors must carry out research in addition to their teaching duties.

5

BRIEF NOTE ON THE TREND OF MEDICAL RESEARCH IN INDIA

In India medical research has extended over very large and varied fields and it is not possible to summarise all lines of work. An outline of the work done upto 1937 on some special subjects may be found in the Indian Medical Review, 1938 by Maj.-General E. W. C. Bradfield. It is proposed to give below a resume of the work done during recent years on some problems which are considered to be of importance to India.

I. **Anaemias :** Establishment of normal standards has facilitated systematic and comprehensive study on various haematological problems.[1-7]

Nutritional macrocytic anaemia : First reference to the incidence of nutritional anaemia in India was made by Mackie[8] in 1929. Wills and Mehta[9] in the following year carefully differentiated the condition from Addisonian pernicious anaemia and reported that the disease, which they named as Tropical macrocytic anaemia, was cured by yeast and whole liver extract. Subsequent workers, Napier[10], Dasgupta[11], Dasgupta et al[12-15], Patel[16], Choudhuri[17] further characterised the condition which is now known as nutritional macrocytic anaemia, and showed that it is due to a combined deficiency of folic acid and vitamin B_{12}, deficiency of folic acid predominating in an average patient. The effect of therapy has been found to vary from case to case but usually the patients with nonmegaloblastic bone marrow respond better to whole liver extract than to refined liver extract, folic acid, vitamin B_{12} or citrovorum factor[12-15, 18-21]. *Pernicious anaemia*—Rarity of the condition in Indians has been shown by Das Gupta and Chatterjea[22].

Hookworm anaemia: Absorption of iron is adequate[23], and where the anaemia is microcytic and/or hypochromic in type, therapy with oral iron cures severe anaemia even in the presence of heavy hookworm load whereas no improvement in the blood picture is seen with anthelmentic treatment alone[24].

Dimorphic anaemia: Anaemia due to dual deficiency of iron and anti-megaloblastic factor is seen in a very large number of cases[25]. Recognition of dimorphic anaemia as a separate clinical entiety has greatly helped the therapy in nutritional anaemias.

Anaemia in pregnancy: Though work on this has been carried out by various workers from different parts of India for many years[25, 26, 27] anaemia in the pregnant woman still continues to be one of the most important causes of the high maternal mortality and morbidity in India[27, 28]. Country-wide preventive measures have been advocated[28a, 28b].

Cooley's anaemia: First seen in an Indian in 1939[29] incidence of Cooley's anaemia in Indians now appears to be quite high[30]. Study of abnormal haemoglobin in these cases has led to the recognition of Haemoglobin E—thallaessaemia disease[31].

Sickle cell anaemia: Cases of sickle cell anaemia and sickle cell trait in Indians have been reported from Assam[32] and South India[33]. From information received one is inclined to think that the condition is present in other parts of the country as well.

Studies in Haematology in all its branches have made immense strides in western countries, but very little attention has been paid to the study of haematology in a specialised way in India though much morbidity and mortality in the country may be ascribed to blood disorders. It is high time that the study of Haematology as an independent subject should be pursued vigorously.

II. **Cancer :** Recent studies in different parts of the country show quite a high incidence of cancer in the suspected cases examined. A national campaign against cancer has been suggested. This problem was discussed by Dr. Mitra in his presidential address last year.

III. **Cholera :** The antigenic structure of V. cholerae as well as other vibrios widely distributed in nature was investigated by Gardner and Venkatraman[34] and elaborate studies were carried out on the immunochemistry of vibrio by Linton and his colleagues[35, 36]. But up till now it has neither been possible to indicate the relationship between the true cholera vibrios and the other so-called N.A.G. (non-agglutinable) vibrios, nor has it been possible to find out what happens to the V. cholerae during the inter-epidemic period. A conjecture by Pandit and Hora[37] on the probable role of 'Hilsa' fish in maintaining cholera endemicity was investigated by Krishnan, Lahiri and others[38], but with negative result. Inspite of what is known about the nature of cholera vibrios, there is still a gap in our knowledge with regard to the epidemiology of the disease. In fact this has hindered to a great extent the formulation of methods for the effective control of cholera, based on scientific grounds. Commendable efforts in this direction are being made by the I.C.M.R. to organise researches with a view to bridge over the gaps in our knowledge.

IV. **Eosinophilia :** The etiology of tropical eosinophilia is still obscure[39]. Concurrently there are two theories with regard to the etiology of tropical eosinophilia—allergy[40-42] and infection[43-45] neither of which has been proved conclusively. Recently an organism belonging to the class Actinomyces has been isolated from the blood of patients suffering from tropical eosinophilia[46] and work is in progress at the School of Tropical Medicine to isolate the same organism from the sputa and to find out the relationship, if any, of the organism with the diseased state.

Organic aracnicals still continue the treatment of choice though equally good results were obtained in a rew cases with sulphapyridine by Lal[47] and with aureomycin by Choudhury[48] and Rao and Krishnan[49].

V. **Epidemic Dropsy :** Epidemiology has been worked out[50] and argemone mexicane[51] used as an adulterant of mustard oil has been incrimated as the causal agent. Physical and chemical tests for the toxic material contained in argemone mexicane have been worked out[52].

VI. **Filariasis :** Filarial diseases causing physical disability and morbidity are found in many parts of India. Although culex fatigans still remains the chief vector in the transmission of filariasis, work by Iyenger[53] has shown that certain anophelenes may also be involved in the spread of filariasis. In India very little work has been done in recent years both with regard to the incidence and pathology of the disease except the interesting experimental studies by Bhaduri and Choudhury[54] in the pathogenesis of lymphodema. Treatment of filariasis continues to be as disappointing as before. In 1952 a Filaria Unit was added to the Malaria Institute of India in New Delhi. The Institute is training personnel in the prevention of filariasis and has been entrusted with National Filaria Control Programme. Personnel to be engaged in the National Filaria Control Project are also trained in the School of Tropical Medicine, Calcutta. The results of the Control programme will be keenly awaited.

VII. **Hookworm :** Hookworm infection is widely prevalent in many parts of India and causes much morbidity particularly in the rural population and hence is of great importance from public health point of view. But up till now very little has been done for prevention or control of hookworm infection in a country-wide scale. Treatment of hookworm infection with indigenous anthelmentic, cashewnuts (Anacardium occidentale) has been found to be quite effective[55] while the resulting anaemia has been successfully treated with iron by Napier and Dasgupta[23] irrespective of the load of hookworm. It has recently been shown by Dasgupta et al[22] that absorption of iron is not retarded in hookworm infection.

VIII. **Indigenous drugs :** Although the credit for isolation of Reserpine from *Rauwolfia Serpentina* and for wide publicity of its good hypotensive and sedative effects must go to the Swiss workers, it must, however, be recorded that potency of the resinous fraction particularly its sedative action was first detected by the workers at the School of Tropical Medicine[56]. It has been shown that reserpine is not the sole hypotensive principle in the total extract and that total alkaloids produce better and more sustained result than reserpine alone. A few new alkaloids from Rauwolfia has been reported by Mukherji[57]. Work on the mechanism of the hypotensive action was carried out by Das Gupta and Werner[58] and Chatterjee and Hausler[59, 60].

Encouraging results have been obtained with *Cardol*[61] obtained from cashewnut shell in the treatment of helminthic infections and with *Psoralea corylifolia*[62] in the treatment of leucoderma. Products isolated from *Pisum sativum* and *Citrus aurantium* are on trial as anti-fetility agents.

Some antibiotics has been isolated from indigenous sources e.g. Pristimorin from[65] *Pristimura indicae*, Pteriygespermin from *Moringa pterygos-*

perma. A saponin, diosgenin has been isolated from *Dioscorea prazeri* which may be utilised in the synthesis of steroid hormones[63].

Attention has been directed towards the propagation and cultivation of medicinal plants, and extraction of drugs and essential oils. Suitable methods have been described of preparation of concentrated pyrethrum from pyrethrin and of emetine from Indian ipecacuanha.

IX. **Industrial Health :** It is only recently that research in Industrial Health has been pioneered in India by the Government of India ; the I.C.M.R. has also sponsored research on occupational health. But barring Ahmedabad Textile Research Association and a few others very little research activity has been shown by private industries in general. Some contribution to research in Occupational Health has been made by the Applied Psychology Departments of some of the Universities particularly by the Applied Psychology Department of the Calcutta University and the Indian Institute of Sciences, Bangalore.

X. **Kala-azar**—*Complement Fixation Test* : Diagnosis of Kala-azar, particularly of early cases has been greatly facilitated by the Complement Fixation Test[64].

Post-Kala-azar Dermal Leishmaniasis : First described by Brahmachari[65] in 1922, various clinical manifestations were described by Acton and Napier[66], Napier and Das Gupta[67], and Sen Gupta[68]. Histopathology of the condition has been worked out by Sen Gupta and Bhattacharji[69].

Cytology of L. donovani : Cytology and cytochemistry of L. donovani has been studied by Sen Gupta, *et al*[70, 71].

XI. **Leprosy :** A refined and standardised protein antigen has been prepared by Dharmendra[72] while almost similar immunological reaction has been obtained by Chatterjee and Bose[13] with an antigen prepared from a chemical fraction of Kedrowsky's bacillus. A distinct advance has been made in our knowledge of immunology in leprosy by Dharmendra and Chatterjee's[74] observations on the development of most cases of leprosy in negative reactors. Khanolkar's[75] observations on the early lesions in leprosy may help in the study of the evolution of leprosy lesions, while Chatterjee's[76] observations on the morphological variants of Myco. leprae in relation to the different stages of its development, and cytochemical constituents of the bacilli and the affected tissues may help in the establishment of host-parasite relationship in leprosy.

A new era in the chemotherapy in leprosy was ushered in 1943 with the use of Promin by Faget, *et al*[77]. Continued use of sulphone in India[78-81] has shown that the simple and economical, Diamidinidiphenyl sulphone (DDS), is the drug of choice in the treatment of leprosy. Chatterjee and Poddar[82] have shown that the leprous skin has special affinity for uptake of radio-active sulphone.

XII. **Leptospiral Infection :** For the first time in 1932 Knowles and Das Gupta[83] noted leptospiral infection in Indian rats, while in 1937 the first case of Weil's disease in India was reported by Das Gupta and Chopra[84] with isolation of L. icterohaemorrhagica in the blood and urine. The first authentic case of leptospiral jaundice in Assam was reporte by Das Gupta in 1941[85]. Different serological types of Leptospira was identified by Taylor and Goyle[86] and by Das Gupta[87] in Andamans. Examination of the kidney substance of rats from infected areas showed the presence of classical L. icterohaemorrhagica in 5 out of 300 animals examined[88]. Unlike the European cases no agglutinin or lysin could be demonstrated in the Indian cases after two years of infection[89].

XIII. **Malaria :** By application of standard methods presence of Glycogen, polysaccharides, acid polysaccharides, nuclosacharides, R.N.A., D.N.A., alkaline phosphatase and cytochromic oxidase have been demonstrated in various species of plasmodia. Similar findings were also made in leptomonads of L. donovani, trypanosomes and other protozoa of man and animals. These substances were found to vary in their disposition in the nucleus and cytoplasm of the parasites while localisation of the substances were found to vary in the different species[90-94].

National Malaria Control Programme : Launched in 1952 in collaboration with T.C.M., who have up till now contributed over 50 per cent of the total expenditure, it has helped to control malaria to a very great extent in all the operating 162 units. The target of 200 units set in the programme shall have to be increased to about 250 units as it has been found that under actual fields operation an average unit could afford protection to 800,000 people and not to 1,000,000 as was supposed in the beginning. This is a great achievement and it is thought that other preventable conditions could also be kept under control if they were tackled in the right way.

XIV. **Maternal and Childhealth :** Till recent years research activities in the fields of Maternal and Child Health have been very limited though infant and maternal mortality and morbidity have been very high. Reliable causes of still births are still unavailable, some work on the subject is under progress. Investigations are also in progress to find out the cause and the rate of infant mortality and morbidity in the rural and urban areas.

Investigations carried out in different parts of India showed that the most important causes of maternal mortality are (i) Puerperal sepsis, (ii) Anaemia and (iii) Toxaemia. With the advent of chemotherapeutic agents and antibiotics, sepsis has been controlled to a great extent. At present a number of investigations are in progress to indicate the cause and the method of treatment of anaemia and toxaemia. Country-wide campaign against anaemia in pregnancy suggested by Das Gupta[28a] and Woodruff[28b] has yet to be implemented.

XV. **Nutrition :** The problem of nutrition is a major public health problem in India. Some of them e.g. lathyrism, beri-beri, epidemic dropsy etc. could be corrected by a change in the dietary but concerted government action only could control most others as in protein malnutrition. Field surveys have indicated widespread prevalence of the condition in infants and children of low socio-economic group in both rural and urban areas. Anaemia in pregnancy is also probably due to malnutrition. Wide prevalence of continued low grade malnutrition is responsible for high morbidity as also to easy susceptibility to infectious diseases. Improved standard of living and better knowledge of food values are essential in the fight against malnutrition. This could only be achieved with state help if a country-wide campaign is made in supplying protective foods to the vulnerable group, otherwise any amount of knowledge would not help the people of the low economic group to augment their intake of protective foods.

XVI. **Plague :** W.H.O. workers have made a highly interesting discovery regarding the reservoirs of plague. They have found that the wild rat *fativa indica*, as a reservoir of plague in parts of U.P. Serological and antigenic structure of B. pestis has been worked out by Seal[95] while improvement of plague vaccine has been effected by Sokhey, *et al*[96]. The frequency of plague epidemics is on the wane while the newly introduced chemotherapeutic agents have proved to be a considerable value in the treatment of plague.

XVII. **Rat bite fever :** Rat bite fever in man due to A. muris has been known to occur in America and British Isles. Recently A. muris has been isolated from the blood of clinical cases of rat bite fever at the School of Tropical Medicine, Calcutta[97]. This appears to be first record of rat bite fever due to, A. muris in India.

Tuberculosis : The introduction of mass chest radiography has helped in the detection of the disease in a very large number of unsuspected cases. The advent of the new drugs have no doubt facilitated the management of tubercular cases, but the incidence of tuberculosis in urban and industrial areas still continues to be very high. To prevent the spread of the disease domicilliary segregation and treatment with potent anti-tuberculosis drugs under the guidance of the clinic will be undertaken in the Second Five Year Plan. As the majority of the cases are from the low-income group, domicilliary segregation in these cases would not be practicable and hence may not produce the desired result.

Low rate of infection has been reported from rural areas. I.C.M.R. has instituted a fairly wide investigation to find out the validity of the observation.

Mass B.C.G. vaccination, offering partial protection has been launched with the help of W.H.O. Though about 30,000,000 have been vaccinated so far, many more remain to be vaccinated. And this must be carried out within a short time and sustained for some years—a colossal task for a vast country like ours.

Fight against tuberculosis is a fight against poverty and sanitation and unless an attack is made simultaneously in all directions, it will be difficult to control tuberculosis in a country-wide scale.

XVIII. **Typhus :** The occurrence of epidemic (louse-borne) and endemic (fleaborne) typhus in India has been recognised in the past. Krishnan and his colleagues[98] investigated the prevalence of scrub typhus (miteborne) in and around Calcutta. Thorough laboratory investigations, including serological tests and animal experiments have made it possible to diagnose about 8-10% of the cases of pyrexia of unknown origin (P.U.O.) as that of scrub typhus.[99] These workers succeeded in breeding the mites in the laboratory and demonstrated transovarial transmission mechanism of the infection in mites.[100]

XIX. **Venereal disease :** Syphilis constitutes a major health hazard to the individual and to the community. About 5-8 per cent of apparently healthy people were found serologically positive to syphilis in Calcutta and Madras while syphilis is stated to be endemic in about 5-10 per cent of the population in the North West and North Eastern parts of the Himalayan region. The mortality and morbidity of infants born of syphilitic mothers is very high. Syphilis is an important cause of blindness in children and of cardiovascular and nervous disorders in the adult. Syphilis thus constitutes a major health hazard to the individual and to the community and it is in the fitness of things that a comprehensive 'National Plan' for the control of V.D. has been proposed during the Second Five Year Plan.

XX. **Virus disease :** A virus research centre has been opened at Poona by the I.C.M.R. in collaboration with Rockefeller Foundation. Training in Virology is imparted to workers deputed from various institutions. Sudden outbreaks of encephalitis in Jamshedpur and other places and of infective hepatitis in Delhi were investigated by workers of the centre and the causal viruses have been isolated.

Comment:

India is a vast country and problems are of various nature. In the preceding paragraphs an attempt has been made to indicate the trend of research activities in some of the prevalent conditions.

It will be seen that during recent years Medical research has not been confined to pathological disorders in man, but studies have been directed towards appraisal of the basic conditions in the host and the parasite, the various changes associated with infection, intoxication etc. and their relationship with social, economic and environmental factors. It is usually agreed that a start in the right direction has been made and if the fundamental studies are carried along with clinical and epidemiological studies many of these problems affecting the health of thousands of peoples in this vast sub-continent will be solved before long.

6

ESSENTIAL PRE-REQUISITIES FOR RESEARCH

In carrying out research in India the following are considered essential pre-requisites :—

I. *Trained personnel*:

India badly lacks in trained personnel suitable for undertaking research work. This is due to a number of factors more important of which are—

(*i*) Paucity of suitable training centres and
(*ii*) suitable employment of research personnel.

(i) *Training centres*:

In the pursuit of research, 'the bottleneck', according to Raymond B. Fosdick, 'is not the lack of funds, it is the lack of capable and thoroughly trained investigators to use the funds'. He further observes that 'we cannot build research without the foundations of trained personnel. We cannot grow orchids in a greenhouse that lacks coal'. Any worker will appreciate the validity of the above statement. We have got some post-graduate short course training centres for malaria, leprosy, virology etc. but there is no place in India where a trainee could learn the grammar of medical science as is afforded by the honours course in Physiology in Oxford. Training in the research institutions even in the narrow spectrum of their activities is very limited, either on account of lack of accommodation as in the S.T.M. or on account of the money-making policy of the institutions as in the Haffkine and other institutes enumerated before. If the research programme for the second Five-year is to be carried out with any degree of success, training of research personnel must be undertaken forthwith in the country itself. I fully agree with Dr. Pandit that training abroad under totally different conditions is not the best preparation for a scientific career in India. Training must be given in the country under local conditions. Dr. Pandit rightly assumes that at least one trained person would be available in the different branches and if allowed to function in the right way a band of trained workers would be available in the course of the next few years and would be in a position to tackle the different problems in the most efficient way. The existing research institutes should be utilised for this purpose if required by providing additional staff from a central pool, the proposed new research cadre proposed by the I.C.M.R., irrespective of any question of provincialision which is slowly but surely snapping the solidarity of the country. Further, if necessary, some foreign teachers may be invited for short periods with the help of W.H.O. and other organisation to give training in some specialised subject, to supplement the teaching.

Training of personnel for research has been helped to a certain extent by grant of fellowships to suitable candidates by Organisations, Associations and Firms, both Indian and Foreign. It is a pity, however, that even the small number of people trained through award of different fellowships could not be suitably employed to pursue their research career in the absence of suitable employment. Organised in the proper way I feel that the present void in our trained personnel would be filled up in no time. For, I know that there is no dearth of intelligent young people in the country and many of them could be moulded into fine research workers provided they are assured of suitable remuneration and stability of service.

(ii) *Suitable employment of research personnel* :

A natural sequele to the question of trained personnel is the question of their suitable employment. It is now realised that the backbone of research is the quality of the research worker. And this quality in the research worker can only be achieved by suitable training and later employment with adequate pay and assured of security of service with provision for old age.

The recommendation of creating a research cadre by the I. C. M. R. is certainly a move in the right direction. Further their recommendation that the research workers should be given some teaching duties and the teachers on the other hand must be made to take up some research work with the idea that the two cadres, research and teaching should serve as complementary to each other are sure to receive universal approval.

I do not, however, agree with the Council's observation that there may be criticism with regard to the question of their ultimate utilisation and hence would urge upon the council to appoint forthwith 50 officers. The remaining 50 posts should be gradually filled up in the course of the next five years. Considering the vastness of the country and the magnitude of the different preventible conditions, 50 officers will, in my opinion, be not too many, but too few, to tackle the different problems in a nationwide scale unless the Council desires that only problems in which they are actively interested should be taken up. The selection of the candidates must be made impartially through open advertisement and without any distinction whatsoever. If this can be implemented bright future for research workers and with it research may be visualised. While implementing this the present personnel in the different research institutes and under the I.C.M.R. must be employed on a permanent basis. On the other hand research personnel must work for longer hours than what is the rule in most institutions. Brilliancy has been rightly defined as 90% perspiration and 10% inspiration and no brilliant work can be achieved without arduous work. Work in the research institutions should not be compared with the work in the administrative offices. But this could only be achieved if workers are adequately paid and have security of service with provision for old age.

II. *Equipment* :

Precise instruments are wholly essential for research. We are, however, still wholly dependent on foreign countries not only for the complex instruments like microscope but for even simple instruments. It is true that in the past research of very high order was carried out in India even in the absence of modern equipments and gadgets, but the present day trend and training necessitate the use of modern equipments and gadgets. This is more necessary as young people sent abroad have the training in first class laboratories fully equipped with precise instruments and time saving gadgets. Equipments and gadgets are now a part and parcel of any research programme and the National Laboratories must be urged to help Research Organisations and Institutions first with the maintenance and repair of instruments brought from abroad and gradually must take up the manufacture of the various equipments required in the country itself.

III. *Animals for research* :

Animals in adequate numbers and of suitable quality are also essential for research and hence every research institute must have a modern animal house of its own. This is all the more necessary in India where animals of known age group are not available from market. Animal houses are necessary not only for keeping animals but for breeding as well and should be built in a planned way. Anybody interested in the subject is referred to the article on the subject by Dr. Lane-Petter, Director, Laboratory Animals Bureau, M. R. C. Laboratories, London in the memorandum on medical research in the Second Five-Year Plan by the I. C. M. R.

IV. *Journals* :

Another essential pre-requisite for research is the Journal—a medium for expressing the results of the research carried in the country. Considering again the vastness of the country and the multitude of problems, the number of journals in the country, is quite inadequate. On account of this as also for better publicity a number of research papers are published in foreign journals. This has double disadvantage, on the one hand it deprives the Indian journals from good papers and on the other hand foreign workers including authors of text books usually take scant notice of the papers published in Indian journals. Immediate steps may be taken to give wide publicity to work carried out in India, if required through the various Indian Embassies all over the world.

It is further suggested that classes for Journalism should be opened in the Local and Central libraries where lessons in journalism should be given to the members requesting for them. It is frequently seen that for want of good presentation and clear expression valuable data are lost in a maze of wilderness and fail to emphasize the high lights in the paper.

V. *Library* :

A library well stocked not only with the recent books and journals but with old volumes as well is also essential. Considering the vastness of the country, there should be at least 4 zonal libraries with one central library of the stature of the library of the Royal Society of Medicine in London. Both local and central libraries must be provided with comfortable reading rooms and other modern amenities and must be kept open for at least 12 hours from 8 a.m. to 8 p.m. The libraries must also be well equipped to provide micro-films and photostatic copies of articles without much delay and at low cost. The facilities of the libraries should be made available to the members only, which may be of two categories, associate membership for fellow and demonstrations and full membership for Professors, Research workers and senior assistants. The membership fee particularly for the associate members should be low. The central government should be entirely responsible for financing and management of the central library while the zonal libraries should be the joint responsibility of the central and state governments.

VI. *Co-ordination* :

Medical problems cannot be solved by medical people only particularly during the present day when vast advances have been made in all branches of science. There have been numerous instances both in the past and in the present when valuable contributions to medical science have been made by non-medical scientists either singly or jointly with medical people.

Lacunæ in many medical problems could be more easily solved by helpful collaboration between medical and non-medical workers. Emphasis should be given to this in future research as there appears to be very little co-ordination even between the two Government organisations viz., I. C. M. R. and C. S. I. R. It is probably with this view that the Bhore Committee recommended the inclusion of representatives of the principal scientific bodies in India and non-medical representatives of allied and fundamental sciences on the Board of the Central Research Body proposed by them. Now that the I. C. M. R. has taken up the function of the Central Research Body, the Governing Body should do well to include such people in the S. A. B. of the I. C. M. R. if need be by increasing the number of members.

VII. *Funds* :

Nothing however could be achieved without adequate funds. It is gratifying to note from the inaugural address of Srí K. B. Pillai, Secretary, Union Ministry of Health, to the annual meetings of the Scientific Advisory Board and Advisory Committees of the Indian Council of Medical Research held in November 1956 at Mysore that a sum of Rs. 412 lacs has been provided for medical research in the Second Five-Year Plan. But it is our greatest misfortune that very little financial assistance for research is received through associations, organisations, firms or private individuals. There is no dearth of wealthy people in the country but there is not a single instance where princely donation was made for medical research as has been made by Rockefeller, Nuffield and many others in the west and in America. Whereas many research institutes have been created and research schemes and projects have been financed by pharmaceutical firms and by public donations in those countries, we in India are almost wholly dependent on Government help. Held from Associations and Organisations though none too generous in the past has been still further curtailed after independence as in the case of Endowment Fund of the School of Tropical Medicine. A change of outlook is urgently needed and unless funds are available from sources other than the Government, progress of research is sure to be retarded. There are plenty of problems requiring urgent solutions, there will not be dearth of men if suitable remuneration is given and it would be pity if these cannot be undertaken for want of funds.

7

RECOMMENDATIONS

It has been fully established that no research is possible without trained personnel. Hence, steps should be taken for the training of ardent young graduates with aptitude for research in the existing research institutions as also in the Medical Colleges where facilities for research must be provided for, where necessary by giving special grants for personnel, equipments etc. Potential research institutions like Haffkine Institute should be freed from their manufacturing duties and should also be utilised as training centres.

The research workers should have equality of pay as those of the Professors of the Medical Colleges as recommended by the Central Health Council ; must have security of service ; the age of superannuation should be increased to 60 and thereafter to be employed, if fit, for every 2 years upto 64th years as has been done in the case of the employees under the C. S. I. R. and should have adequate provision for old age. The scheme for employment of retired Research Workers under consideration of the Government should be implemented as early as possible. The Directors of institutions must be provided with adequate funds and should be given powers to spend the same without routinely going through the process of red-tapism. Personnel should be selected through open advertisement on merit only ; great care being taken in the selection of research personnel and still greater care in the selection of the Heads of Department and the Director of the institutes. It is probably not a bad idea to have a Director for 2 to 3 years by rotation from amongst the Senior Workers of the Institute ; the routine administrative work being entrusted to a competent, non-medical Secretary. The procedure, if adopted, will not shunt off a research worker permanently from the field of active research, and might infuse new ideas for the development and growth of the institute. The discrepancy in the pay and service conditions of the personnel in the different institutions should be immediately removed where necessary through adequate subsidy from the Government, State or Central. At the same time the workers must also help to make research successful by working longer hours and wholeheartedly without wasting their time and energy in other activities.

Necessary adjuncts to research are equipments and animals to carry out research in efficient way ; journals to disseminate the knowledge gained through research and libraries where one could gather information on similar and allied problems, and these should be adequately provided for. Manufacture of equipments should be started with simple instruments, breeding of animals should be taken up which would assure supply of healthy animals of proper age to research institutes ; more scientific journals should be started and zonal libraries should be created. The knowledge gained through research should be disseminated not only through medical journals but through lay press as well so that full advantage of the results of research could be made known to the public. And to make medical research a success there must be co-ordination with the scientific institutions, medical and non-medical, national and international. But above all ample funds must be provided for research not only by Government, State and Central but by Organisations, Firms particularly pharmaceutical firms and by individuals, either singly or collectively. Steps should also be taken to utilise the available funds for research on urgent problems in a co-ordinated way and not fritter away its meagre resources on disjointed schemes. Assured of suitable employment there should not be any dearth of bright young graduates to take up research as a career. And I feel there are enough men in the country itself to take up supervisory work of research programmes in the different fields and to train up future personnel for research. I fully agree with Dr. Pandit that even with one trained worker in any field a band of workers could be trained in that field in a short time, who in their turn could train up others and thus solve the problems of trained personnel in the country. There are a number of problems awaiting solution and these should be tackled in a co-ordinated way in the manner indicated above.

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SECTION OF AGRICULTURAL SCIENCES

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THE PHENOMENA OF INSECT PARASITISM AND THEIR PRACTICAL UTILISATION IN THE BIOLOGICAL CONTROL OF INSECT PESTS

Ladies and Gentlemen,

I am deeply sensible of the signal honour that the members of the Indian Science Congress Association have done by electing me as the President of the Agricultural Sciences Section of the Indian Science Congress 1957. The honour is all the more as I contemplate that the present Science Congress Session is being held in conjunction with the centenary celebrations of the Calcutta University, a great centre of learning that has always been in the vanguard of both teaching and research in all fields of human endeavour, particularly sciences and humanities. The role of agricultural sciences in the present context of the development of our country needs no emphasis. And I must particularly recall that this is the fourth time that an entomologist has been called upon to guide the deliberations of the Agricultural Sciences, my distinguished predecessors Mr. M. Afzal Hussain, Dr. T. V. Ramakrishna Ayyar and Shri Y. Ramachandra Rao having presided over the section in the earlier Science Congress Sessions held at Patna in 1933, Lahore in 1939 and Calcutta in 1943. I take this as a sign of the increasing awareness and recognition of the vital role of entomology in increased crop production by the members of the Indian Science Congress Association. I have chosen for my address a subject that has made great advances within recent years. If the phenomena of insect parasitism with their high degree of specialisation and other complexities is a fascinating problem in pure entomology, their exploitation by economic entomologists in the subjugation of insect pests of agricultural crops, orchard trees and noxious weeds reads almost like a romance in the story of applied entomology. I have been deeply interested in this problem for more than two decades and so you will expect me to devote the major portion of my address to the research work carried out by me, my colleagues and my students in the Section of Insect Parasitology, of the Division of Entomology, Indian Agricultural Research Institute, New Delhi. I shall now discuss in some detail the research work that has been carried out in our country on various aspects of insect parasitism and their practical application in the biological control of insect pests and noxious weeds.

TAXONOMIC ENTOMOLOGY

In the history of biological science it has been the experience of workers that to stimulate further research and make enduring advances in a particular aspect of a biological problem we must make use of the knowledge and methods that we already possess on a rational basis. This is more so in the field of pure entomology especially systematic entomology. Here the first requisite for making a first class contribution to our knowledge of a particular group or family is to have an uptodate catalogue of the species and their description. There can be little doubt that research work in parasitic Hymenoptera has suffered a good deal in our country for lack of catalogues and fauna of the various families that constitute this economically important group of insects. As Clausen (1940) observes "The Hymenoptera are the dominant order among the entomophagous insects both as regards the number of species having that feeding habit and in the frequency and effectiveness with which they attack the insect pests of agricultural crops". Studies on the Chalcidoidea and the Serphoidea are of immense interest not only to the insect taxonomist, but as in the case of parasite Hymenopterons, such as Ichneumonidae, Braconidae, Bethyloidea and others to the economic entomologist as well as several representatives of these groups are parasitic on crop pests, that levy a heavy toll on agricultural crops. Before the economic entomologist could utilise any of these species for the control of these pests, it is most essential that the identity of the species is settled beyond doubt. The earliest contribution of importance to our knowledge of Indian Parasitic Hymenoptera was by Ramakrishna Ayyar (1928) who studied South Indian Braconidae of the sub-family Vipioninae. In this memoir Ramakrishna Ayyar besides cataloguing all the known species of South Indian Vipioninae described also many new species belonging to this sub-family. But the real credit for pioneer work in the field of insect taxonomy in parasitic Hymenoptera in our country goes to Dr. M. S. Mani, now Deputy Director, Zoological Survey of India, Calcutta. Working in the same institution in a far more humbler capacity more than two decades ago, it is astonishing how Dr. Mani produced a series of publications (1935, 1936, 1937) that brought to our country both honour and renown and secured for him a foremost-place among the great insect taxonomists of the world. During my visit to the United States of America in the summer of 1955 under a leader—type programme sponsored by the Foreign Operations Administration in cooperation with the United States Department of Agriculture and Land Grant Colleges, I was delighted to hear many eminent entomologists in that country speaking in high appreciative terms of Dr. Mani's contributions to the taxonomy of this group. The titles of Dr. Mani's and his students' contributions to the taxonomy of parasitic Hymenoptera number more than a hundred and in an address like this where more than one aspect of insect parasitism is dealt with, it is not possible to refer except to the more important ones. In his earlier papers published in the Records of the Indian museum Dr. Mani (1935, 1936, 1937) recorded a number of hitherto unknown species. His interest in the studies on these groups continued unabated after leaving the Zoological Survey of India in the early thirties to take up a research position in the Division of Entomology in the Indian Agricultural Rsearch Institute, New Delhi. While working in this capacity he not only published the descriptions of a large number of hymenopterous parasites in the Indian Journal of Entomology (1939-1941) and the Indian Journal of Agricultural Science (1939) but also catalogued all the species so far known from India, of the Chalcidoidea

(1938) Evanidae (1939) and Serphoidea (1940). In his catalogue of the Chalcidoidea Dr. Mani gave the references to 369 Indian species falling under 170 genera, of which 21 were described as new by himself in the short span of about four years from 1935. To this he himself added 22 more species (1939) and another eleven species (1941). Of these several were described for the first time. Muzzafar Ahmed (1946) later contributed the descriptions of a few new species working on the material at the Indian Agricultural Research Institute. On the Serphoidea Dr. Mani's catalogue (1940) contains references to 116 species falling under 47 genera and no appreciable additions to this have since been made.

I have for a long time been deeply interested in Ichneumonidae, a family of great economic importance whose members attack many injurious insect pests of agricultural crops in the field and grain in storage. The Indian Council of Agricultural Research generously came to my help by providing me a research fellow to assist me in my studies in the taxonomy of this remarkably interesting goup of insects. Very little or practically no work has been done on Ichneumonidae in India since Morley (1913) wrote his Fauna of British India, Hymenoptera, Volume III 43 years ago. In this Fauna Volume he dealt with only three subfamilies namely (1) Pimplinae (2) Tryphoninae and (3) Ophioninae. He intended to treat the subfamilies Gelinae (=Cryptinae) and Ichneumoninae in a separate volume which unfortunately did not come out.

After Morley this family of great economic importance and biological interest has been totally neglected in our country. Since Morley wrote his Fauna in 1913, taxonomic work has made such advances that even his work completed in the first decade of the present century has been totally out of date as the whole family has been reclassified with new subfamilies, tribes, genera and species with new synonyms in other countries especially U.S.A. and Britain. Many names have been redefined. Wrong names applied to many genera and species have been corrected. It is unfortunate that workers on Ichneumonidae in our country should use this volume for their taxonomic research work. Narayanan and Kundan Lal (1953, 1954, 1955, 1956) have now completed revisionary studies of this family. Other contributions of importance are on Braconidae by Lal (1938-1942), on Cynipoidea by Narayanan (1942) and Subba Rao on Braconidae (1955) and Chalcidoidea (1955). The Chalcid parasite recorded by Subba Rao (1955) is suspected to parasitise the wax moth *Galleria mellonella* L. and is perhaps the largest parasite ever-recorded in India in this genus.

Narayanan and Snehamoy Chatterjee (1952) described a new species of *Triphleps* (Hemiptera : Heteroptera : Anthocoridae), *Triphleps ramae* a predator of some of the pests of stored cereals.

MORPHOLOGY

Within recent years a number of contributions to our knowledge in the morphology of Indian parasites have been made from the parasite section of the Indian Agricultural Research Institute. I shall now make a brief and passing survey of the more important findings. Subba Rao (1954) in discussing the articulation of propectus with the head in the Dryinid *Lestodryinus pyrillae* Kieffer has shown that the cervical apodemes actually articulate with the occipital condyles. This type of articulation facilitates the all round movement of the head which is most essential for a parasite of this family that has to catch hold firmly its host which is a nymph of the sugarcane leaf hopper *Pyrilla perpusilla* Walker to lay its egg.

Narayanan and Subba Rao (1955) have worked out the anatomy of the female reproductive system of *Bracon gelechiae* Ashmead a pre pupal parasite of the potato tuber moth *Gnorimoschema operculella* Zeller. The reproductive organs of the parasite consist of a pair of ovaries, the poison glands, the lubricating glands, the spermatheca and a number of globular secretory cells around the poison canal. The mechanism of the functioning of the poison glands has been described as also the importance of the newly discovered valve controlling the flow of the poison from the gland to the host through the ovipositor canal. Careful observations made, during the act of oviposition and a detailed study of the structure of the female genetalia, have lead to a revision of the old conception of the mode of oviposition. The egg which is at least 22 times larger than the greatest diameter of the ovipositor canal passes through it in a compressed state like a thread. It is suggested that a secretion of the globular cells helps to soften the otherwise brittle chorion. The chorion is thus able to withstand the considerable pressure exerted on it during the process of stretching to which the egg is subjected in its passage through the ovipositor canal. It can be assumed that the stretched chorion regains its normal shape and rigidity as soon as it comes into contact with the atmosphere.

Narayanan and Thakare (1956) have studied the immature stages of seven different Braconid forms namely *Bracon gelechiae* Ashmead, *B. chinensis* Szep., *Stenobracon deesae* (Cameron) *Bracon brevicorins* wesmael. *Bracon gelecliae* sub. Sp., *Bracon greeni* Ashmead and *Chelonus narayani Subba Rao,* for the first time. These studies reveal differences not only in the various stadia of a single species but also in the comparative morphology of the various species in the same stage of development. Narayanan, Subba Rao, & Thakare (1955) studied the mouth parts, especially, the mandibles of all the seven forms which have specific characters. For example the mandible shows specific differences in the shape of the basal plate, the number of comb-like teeth and the general outline. Certain species possess saw-like teeth on the mandibles.

Narayanan and Thakare (1955) carried out investigations on the applicability of Dyar's law to the immature stages of certain forms of Braconidae namely *Bracon gelechiae* Ashmead, a sub species of *Bracon gelechiae* Ashmead and *Bracon brevicornis* Wesmael. It was found that the head widths of *bracon gelechiae* Ashmead, a sub species of *Bracon gelechiae* and *Bracon brevecornis* Wesmael on measuring gave 1·3018, 1·2991 and 1·2851 as the growth factors respectively. Calculated head widths obtained by the application of these growth factors showed a close approximation to the observed head widths. It was concluded that there were five larval instars in each of the three Braconids studied. Ripley and Calvert (1923, 1929) tried the use of the reciprocals of Dyar's ratio but failed to arrive at any definite conclusions. The use of the reciprocals was not tried during the present investigations because the direct application of Dyar's ratio gave significant results. Selection of material for study at random as proposed by Taylor (1931) greatly helped in obtaining these significant results. Overlapping of the observations during the successive instars as seen by Glover (1934) in *Bracon tachardiae* Cameron could very well be avoided by examining the instars under the high power of a microscope. Finally plotting the head width measurements of all the three species on a graph paper provided a means for comparing them. This was also found useful in the separation of the closely related forms developing under identical environmental conditions. Narayanan, Subba Rao and Kaur (1956) while studying the biology of the parasite of the pea leaf minor *Phytomyza atricornis* (Meigen) made detailed observations on the morphology and the distribution of the tracheal system in the parasite, *Solenotus* species and *Rhopalotus* species. The trecheal system in *Rhopalotus* sp. is remarkable in many ways. The respiratory system in *Rhopalotus* represents the transitional type of endoparasitic larva. Parker and Thompson (1925) have described such a type of transitional endoparasitic larva. The chief characteristics of this larva are the absence of both the caudal appendage and the open tracheal system in the early instars. Subba Rao (1954) studied in great detail the external morphology and musculature of the Dryinid *Lestodryinus pyrillae* Kieffer, a nymphal parasite of the sugarcane leaf hopper *Pyrilla perpusilla* walker.

Venkatraman and Subba Rao (1934) studied the mechanism of oviposition in *Stenobracon deesae.* (Sameron). These studies deal with the structure of the ovipositor and the accessory organs.

BIOLOGY

A detailed study of the bionomics and the biology of a parasite is a definite pre-requisite for the successful introduction and the establishment of the parasite from one part of the country to another or from one country into another. In the case of phytophagous parasites the biology forms the basis for their control and subjugation. The life cycle of a large number of parasites have been studied in the Indian Agricultural Research Institute. Narayanan (1936) studied the biology of *Apanteles flavipes* Cameron (Braconide : Hymenoptera) a larval parasite, of the stem borers of sugarcan *Chilotraea infuscatella* (Snellen) and *Diatreaea auricila* Dudgeon. This parasite had not been definitely recorded in India before from either *Chilotraea infuscatella* or *Diatraea auricilia.*

Narayanan (1936, 1938) reared *Stenobracon deesae* (Cameron) (Braconide : Hymenoptera) from the root borer of sugarcane. This was the first time that this parasite was reared from the root borer of sugarcane. The percentage of parasitism observed in the field was 3 to 5 when the host population was small during the month of April.

Narayanan and Choudhury (1954) again studied the biology of the parasite in great detail in the laboratory and some very interesting conclusions were arrived at. The female *Stenobracon* normally avoids laying eggs on hosts that are already parasitised by its own kind, when unparasitised hosts are available ; but in the absence of healthy hosts or when these are too crowded, parasitised hosts are also attacked by it. The phenomena of discrimination between parasitised and unparasitised host and of the change of sex ratio with change of hosts have been studied. It is suggested that the ovipositor enables the parasite to recognise the host and the stimuli received by the ovipositor from the host influence the functioning of the spermatheca which in turn controls fertilisation and finally the sex of the progeny. Pruthi and Mani (1940) published a bulletin entitled "Biological notes on Indian parasitic Chalcidoidea". They also made a contribution on the distribution of the host and habits of Indian Serphoidea and Bethyloidea (1942). Both these contributions deserve special mention. Narayanan (1936, 1941.) studied the biology of *Apanteles paludicolae* Cameron a larval parasite of the Pterophorid caterpiller *Sphenarchis caffer* Zeller. He (1941) also studied the biology of *Apanteles pusaensis* Lal, a larval parasite of the leaf roller of grape vine *Sylepta lunalis* Guen. Narayanan (1942) studied in detail the bionomics and life history of *Coniopteryx pusana* Withycombe, a predator on the eggs of *Pyrilla perpusilla* Walker. This predator along with other parasites of *Pyrilla* keep the pest under check.

Narayanan and Thakhare (1955) studied the bionomics and the biology of *Chelonus narayani* Subba Rao. *Heliothis armigera* F. is a very serious pest of gram in many states of India especially the Madhya Pradesh. One of the serious pests of juar, which is the poor man's food, is the stem borer *Chilo zonellus* Swinhoe. For the first time in this country an egg-larval parasite *Chelonous narayani* Subba Rao was reared from both these pests and the biology studied in great detail by Narayanan and Thakare (1955). Subba Rao (1955) has described this species which is new to science. This parasite was successfully bred on the eggs of *Corcyra cephalonica* Stainton. Detailed studies on the mating habits, preoviposition period, larval development and seasonal distribution have been made. The female parasite oviposits within the egg of the host and the newly hatched parasitic larva awaits the complete development of the host embryo and enters into the host just prior to its hatching out. This is an extraordinarily interesting phenomenon. Its further life is passed within the host body and the full grown parasitic grub emerges out of the host body and pupates within the cocoon of the host. The incubation period of the egg is ten to fifteen hours ; the larval period thirty to forty five days ; the pupal period ten days at an average temperature of 27°C. and 75 percent relative humidity. The maximum longevity of the female is about twenty five days when fed with split raisins. The parasite is observed to breed parthenogenetically even when males are provided for mating. The progeny, however, consists of only males. The parasite is observed in the field on *Heliothis* host during the winter months of February and March and on *Chilo* host during the summer months of June and July. It is interesting to note that the parasite has adapted itself to low as well as high temperatures.

Again for the first time in the Indian Union a parasite new to science of the genus *Apanteles, Apanteles angaleti* Muesebeck (Vipionidae : Hymenoptera) has been reared from the pink boll worm of cotton *Pectinophora* (*Platyedra*) *gossypiella* Saunders by Narayanan and others (1954). Thousands of the parasites were reared in the parasite laboratory attached to the Entomology Division of the Indian Agricultural Research Institute and sent to the United States of America for mass breeding and colonisation in the cotton growing states of the south and south west of that country. The biology of this interesting species was studied by Narayanan, Subba Rao and Gangrade (1955 and 1956). *Apanteles angaleti* Muesebeck is a solitary endoparasite and has great potentialities for the control of the pink boll worm of cotton. It is interesting to note that the incubation period lasts only a day while the life cycle twenty five to forty days at an average temperature of 25°C. and relative humidity of 70 percent.

Recently Narayanan, Subba Rao and Kaur (1956) have studied the biology of the parasites of the pea leaf miner *Phytomyza atricornis* (Meigen). The leaf miner is a serious pest of several crops of economic importance. The host range is considerable and Ahmad and Gupta (1941) have listed twenty nine species of plants comprising fourteen families. *Solenotus* sp. is an ectoparasite of the leaf miner and *Rhopalotus* sp. is an endoparasite of the same. One more Braconid internal parasite of the leaf miner has been reared. In the phase of multiparasitism *Rhopalotus* sp. survives and the Braconid is killed in the early stages. This is the first record of multiparasitism in our country. The life histories of *Solenotus* sp. and *Rhopalotus* sp. are more or less similar. In both the cases there are five larval instars. *Solenotus* larvae feed only on the blood of the host whereas those of *Rhopalotus* feed on the blood as well as on the internal organs. The pupa is naked in the former whereas it is not so in the latter. In both the cases the life cycle is completed in about 10 to 14 days under room temperature when the mean minimum and maximum temperatures ranged between 75°F. and 79°F.

Snehamoy Chatterji (1953) made a contribution to our knowledge of the biology of *Chaetostricha mukerjii* Mani, an egg parasite of *Bruchus analis* Fabricius. The same author (1954) also studied the biology of *Bruchobius* laticeps Ashmead parasitic on *Callosobruchus chinensis* Linnaeus.

Again, Snehamoy Chatterji (1955) studied the biology of a predator and a parasite viz. (i) *Triphleps sinui* Narayanan and Chatterji, (Rhynchota : Anthocoride), a predator of some of the cereal pests viz., *Latheticus oryzae* Waterhouse and *Oryzaephillus surinamensis* Linn. and (ii) *Aplastomorpha calandrae* (Howard), a parasite attacking the larval and the early pupal stages of *Rhizopertha domionica* Fabricius, *Calandra oryzae* Linn., *Bruchus analis* Fabr. and *Callosobruchus chinensis* Linnaeus. The potentialities of this predator in the biological control of the stored grain pests mentioned above are, however, limited. Though its life cycle is much shorter than those of the two hosts, the high mortality among the brood of the predator in April and their cannibalistic habits preclude them as ideal agents in the biological control of these pests.

In *Aplastomorpha calandrae* (How.) he studied the developmental period, mating habits, sex ratio and viability of eggs. This parasite is useful in that it attacks both the laval and early pupal stages of its host.

Narayanan and Kundan Lal (1953) studied the bionomics and biology of three Chalcid egg parasites of *Pyrilla perpusilla* Walker occurring in Delhi. *Tetrastichus pyrillae* Crawford first appeared in October, 1949 in the field. In December two more chalcid parasites, namely *Ageniaspis pyrillae* Mani and *Cheiloneurus pyrillae* Mani, made their appearance. In January and February 1950 only *Tetrastichus pyrillae* Crawford and *Ageniaspis pyrillae* Mani were observed. Due to the presence of *Tetrastichus pyrillae* Crawford for a longer period in the field coupled with its high incidence of parasitism, it is the most important of the three species of chalcid egg parasites already mentioned above.

ECOLOGY

Ecology in relation to parasites is a study of these organisms in relation to their environment. The importance of the study of the ecology of the parasites needs no emphasis. The parasites have to function in nature where there is always the interaction of several ecological factors of which temperature and humidity are the more important ones. The effectiveness of the parasite will naturally depend upon its relation to the environmental factors.

We have been deeply interested in this problem in the Indian Agricultural Research Institute, for the last few years and have studied in some detail the ecology of several parasites. I shall now briefly summarise the more important of these studies.

Narayanan (1949-50) and Venkatraman and Govil (1952) studied the effect of low temperature on the egg parasite *Trichogramma evanescens minutum* R. The effect of low temperature (refrigeration) on the viability, longevity, fecundity and sex ratio of the parasite was undertaken to find out if parasitised *Corcyra* eggs could be stored at a temperature of 10-12°C, in a refrigerator for a definite period. The results of these studies have shown that (a) the most suitable stage for storing at low temperature was four days after parasitisation, (b) the viability (percentage emergence) was not affected up to a period of fifteen days of refrigeration, (c) the effect of refrigeration on sex ratio was not in evidence up to ten days, beyond which period there was a gradual increase in the percentage of females, (d) the longevity of adult parasites was not affected up to fifteen days of refrigeration. The results clearly showed that the parasitised *Corcyra* eggs four days after parasitisation could be safely stored in a refrigerator at a temperature of 10-12°C. for about fifteen days. The importance of these findings in the colonisation of the parasites in the field needs no emphasis.

Narayanan (1952) studied in detail the effect of different temperatures and humidity on the longevity and fecundity of *Trichogramma evanescens minutum* R. The parasites were bred at the optimum temperature and humidity (80° F, and 75 percent humidity) and then were transferred to 68°F. and 45 percent R.H. and were allowed to breed. Similarly parasites bred at an optimum temperature and humidity were allowed to breed at the same temperature but at different humidities, namely, 45, 65, 75 and 85 percent. In another set of experiments the parasites were bred at 68°F. and different humidities and they were kept at the same temperature and relative humidity for further observations on longevity and fecundity. It was seen from the experiments that at low humidity (45 percent) parasites behaved better and lived longer when they were bred at 80°F. and 75 percent relative humidity and then transferred to 68°F. and 45 percent relative humidity than those that were bred at 68°F. and 45 percent relative humidity. But in the case of other humidities the results were reversed that is, the parasites under different conditions lived longer when they were bred at 68°F. and 65 percent, 75 percent or 85 percent relative humidity and then kept at the same temperature and humidities than those parasites bred at 80°F. and 75 percent relative humidity and then transferred to 68°F. and different humidity series. The fecundity of the parasite was always better when it was bred at 68°F. and any of the relative humidities experimented upon in this series and then kept at the same temperature and humidities, than those that were bred at 80°F. and 75 percent relative humidity and then transferred to 68°F. and different corresponding relative humidities. The statistical analysis has given a highly significant value to these results.

Biometer for *Trichogramma evanescens minutum* Riley.

Within recent years several attempts have been made to liberate and colonise the parasite *Trichogramma evanescens minutum* Riley in different parts of India to control the stem and root borers of sugarcane. At some places the parasite has been found to bring about a significant reduction in the pest population while at other places no useful effect of liberating this parasite could be detected. This inconsistency in the results obtained at different centres indicated the urgent need for critical ecological studies on the parasite. As temperature is the one most dominant ecological factor controlling the rate of development and the number of generations in unit time which in their turn determine the successful role of the parasite, investigations were carried out to construct what is called a biometer for this parasite by Pradhan and Peshwani (1954).

A biometer is based on a new conception developed by Pradhan (1946) in the section of ecology of the Division of Entomology of the Indian Agricultural Research Institute. It is an instrument meant to estimate the developmental period of an insect under the actual fluctuations of temperature in nature. There was no satisfactory or practical method for this purpose before the invention of biometer. It consists of a thermograph chart which is transparent and in which the horizontal lines instead of showing temperature, indicate the calculated rate of development of the insect under study—*Trichogramma evanescens minutum* Riley in the present case—corresponding to different temperatures. When this transparent chart is superimposed over the thermograph tracing we can directly read the rate of development at different points of the time scale. Further as the ordinate of this chart represents the rate of development and the abscissa the time, the area below the temperature tracing directly gives the amount of development. However, the different portions of the area are not equal in value because the relation between temperature and rate of development is not linear. Hence the area is estimated not on the basis of plannimeter but by counting the cells formed by horizontal and vertical lines ; these cells differ in actual area but are equivalent in developmental value.

By the help of the biometer constructed for *Trichogramma evanescens minutum* Riley it is now possible to determine fairly exactly the time taken by the parasite to complete its developmental cycle under any range of temperature fluctuations howsoever irregular it might be. Actual observations under field conditions have shown that the determinations by the biometer are far more accurate than those by any other means. Now this instrument is being used to predict the areas in which *Trichogramma evanescens minutum* Riley can be expected to succeed.

Narayanan, Angalet, Subba Rao and D'souza (1954) studied the effect of low temperature of the pupae of *Microbracon brevicornis* Wesmael on the pigmentation of the adult.

The conclusion from these studies is that pigmentation in this case is perhaps a physiological phenomenon caused by the inability of cells to dispose of the break down products of metabolism in chilled pupae at low temperature ; these products tend to increase and accumulate as the period of refrigeration is extended. This explanation supports the hypothesis put forward by Cordier (1928) that "the production of melanin is some times regarded as a mechanism for disposing of toxic phenols arising as breakdown products in metabolism".

Narayanan, Subba Rao and Thontadarya (1956) studied in detail the effect of temperature and humidity on the rate of development of the immature stages and the longevity and fecundity of *Apanteles angaleti* Muesebeck. *Apanteles angaleti* is a vipionid parasite of potential importance in the control of pink boll worm of cotton, *Pectinophora* (*Platyedra*) *gossypiella* Saunders which is a cosmopolitan pest and is found throughout the world wherever cotton is grown. The ecology and the rate of development of the parasite under temperatures 12°C., 15°C., 20°C., 25°C., 30°C., 35°C. and 40°C. and relative humidities of 65 percent and 85 percent were studied in detail.

Multiparasitism and Superparasitism

Two very important factors affecting the rate of reproduction in parasites are multiparasitism and superparasitism. Superparasitism has been defined by Fiske (1910) as a phenomenon "where an individual host is attacked by two or more species of primary parasites or by one species more than once". The definition as given above by Fiske clearly embraces two distinct phenomena ; one phenomenon where the individual host is simultaneously attacked by two or more species of primary parasites and the other where the individual host is attacked by a single species of primary parasite more than once. The former phase of parasitism is now known as multiparasitism and the latter phase superparasitism.

Multiparasitism

Narayanan, Subba Rao and Kaur (1956) studied the phenomena of multiparasitism in the pea leaf miner *Phytomyza atricornis* (Meigen) by the Eulophid *Rhopalotus* sp. and a Braconid. Both are endo-parasitic. Several hundreds of dissections of the host larvae have always revealed that the Braconid is the one that succumbs. It is surprising to see that the Braconid larva which is several times larger and endowed with a pair of powerful sickle shaped mandibles succumbs to the effects of multiparasitism. The hypothesis that some toxic product secreted by one species necessarily kills the other, does not hold good. In this particular case it is probable that the first and the second instars of *Rhopalotus* species derive their oxygen from the host blood, as they feed on them, and by the time the blood becomes scanty the open tracheal system gets established. The braconid gets its oxygen from the host blood through the integument and the caudal appendage, only when the host is living. Hence, the moment the host larva which is already parasitised by the braconid is again parasitised by *Rhopalotus,* the Braconid immature stages are killed due to lack of oxygen rather than through any other means. One more supporting observation is that the majority of dissections of the host have always revealed the first instar living Braconid larvae and a number of eggs of *Rhopalotus* species. When the dissections revealed first instar *Rhopalotus* larva the Braconid was invariably dead.

Superparasitism

One of the parasites that has attracted the attention of the entomologists all over the world is the chalcid wasp *Trichogramma evanescens minutum* Riley. Narayanan, and Mukherji (1953) and Narayanan and Chacko (1954) studied the phenomena of superparasitism in *Trichogramma* parasite in great detail. These studies show that in this parasite the instinct to oviposit soon after emergence and almost immediate mating is so great that it does not even leave off a host egg quickly and attacks and oviposits on the same egg twice or thrice from different angles although it might have fresh unparasitised host eggs by its side and all around it. The urge for egg laying is so great that this parasite sometimes lays two eggs in a host during a single insertion of the ovipositor. This explains as to why (a) this parasite sometimes fails to parasitise completely its host even if the host number is limited in relation to the egg-laying capacity of the parasite and this is not simply by mistake as Salt (1937) observed ; (b) superparasitism occurs both at high and low density of host egg population. If we accept the theory of discrimination and restraint enunciated by Salt, there should be no superparasitism when the density of the host population is high. The same explanation holds good also when a female parasite oviposits in an egg already parasitised by another, especially when fresh unparasitised host eggs are available by the side of the parasitised ones. The discrimination is, perhaps, there, but that is sometimes overruled by its eagerness to oviposit and by which superparasitism really occurs. Our observations further show that this parasite is unable to distinguish between a healthy and a damaged egg, for instance an egg pricked by a needle, for oviposition but leaves off a damaged egg that has been completely crushed and dried up. Neither can this parasite distinguish between a fertilised and an unfertilised host egg for oviposition. These observations, therefore, clearly indicate that superparasitism is not in any way dependent on the nature of the host egg.

The present investigations have also shown that superparasitism progressively decreases with the increase in host density for a single female but is never absent. Superparasitism seems to be governed more by the number of host eggs available rather than the period of exposure.

Further research work show that the ability to refrain from superparasitising the host eggs varies from parasite to parasite. All the host eggs do not get parasitised, especially when they are in clusters, even though a few host eggs are available. Also out of a few host eggs that are available, some get parasitised while others are not parasitised at all. Usually two and very rarely three parasites emerge from a superparasitised egg of *Corcyra cephalonica* Stainton.

When 50 eggs of *Corcyra* were exposed to a single mated female for one hour, about half their number were left unparasitised. When the time of exposure was increased to 2, 4, 8, 16 and 24 hours, no superparasitism was observed. When the number of host-eggs was reduced to 40, 30, 20, 10 and 5, very little of superparasitism was observed. When the time of exposure was increased to 2, 4, 8, 16 and 24 hours and the number of host-eggs were reduced to 10 and 5, high superparasitism was observed. When host eggs were exposed in clusters instead of evenly spreading them, superparasitism was observed. The maximum number that could complete the life-history and emerge from a single host-egg was three. Usually two emerged. It was observed that parasites that emerged from highly superparasitised condition were unable to mate with the healthy ones.

Field colonisation of *Trichogramma evanescens minutum* has been found unsuccessful in several cases and for this reason there is a school of thought that has doubted the utility of the parasite for the biological control of insect pests especially the borers of sugarcane. But the observation made in the laboratory and the data marshalled during the course of the present studies lead the authors to the conclusion that superparasitism is a potent factor which determines the success of the colonisation. For successful colonisation it is suggested that when the parasites are reared in the laboratory for the mass liberation, every precaution should be taken to avoid superparasitism of the host eggs.

Narayanan, Venkatraman and Sen Gupta (1948) and Narayanan and Subba Rao (1955) studied superparasitism in *Bracon* (*Microbracon*) *gelechiae* Ashmead. in some detail. This is an ectoparasite of the larvae of the potato tuber moth *Gnorimoschema operculella* Zeller.

In the course of experimental studies on the host selection by *Bracon gelechiae*, it was observed that superparasitism had a direct bearing on (1) the size of the individuals bred, (2) the number of adults bred per host and (3) the sex ratio of the resultant off-springs. It was found that superparasitism as a result of over-crowding of adult parasites in the oviposition cages is one of the causes of the low rate of breeding of *B. gelechiae*.

In cases where more than one parasite grub shared a single host it was found that as the number of parasite grubs per host increased, the size of the individual parasites decreased and in certain cases, degenerate forms appeared as a result of over-crowding and consequent insufficiency of food. These degenerate forms, "runts" as described by Salt (1940), were very inactive, short lived, and in all cases, died before laying eggs. Structural deformities, such as modified antennal segments and reduced wings were very pronounced in many cases. In certain cases, the parasitic grubs, instead of spinning cocoon, turned into naked pupa which did not develop into adults.

It was also observed in the course of these studies that the number of parasite grubs sharing a single host for their development had a direct bearing on the sex ratio of the adults that emerged.

It was observed that the production of excess males in many cases was the direct effect of inadequate external stimulation of the spermatheca, which depended on host suitability. In gregarious species like *M. gelechiae* the male sex predominates because of differential mortality resulting from superparasitism. It is evident that the haploid male is less affected by larval starvation than deploid males and females.

HYPERPARASITISM

In addition to multiparasitism and superparasitism there is a far more complex phenomenon occuring in nature :

"Big fleas have little fleas upon their
back to bite 'em
And little fleas have lesser fleas
and so *ad infinitum.*"

So we come to the phenomenon of Hyperparasitism. Narayanan, Venkatraman and Subba Rao (1951) recorded a Pteromalid hyperparasite attacking *Stenobracon deesae* Cameron. The pteromalid selects fairly advanced pupae of *Stenobracon* for oviposition. Generally, only one hyperparasite is found to emerge from a single pupa. The female wasp starts laying eggs soon after emergence, if a host of suitable stage is provided. The female pierces the tough parasite cocoon by means of its long ovipositor and lays eggs inside the abdomen of the pupa.

Narayanan and Subba Rao (1953) reared another Eurytomid hyperparasite *Eurytoma* Sp. from the pupae of *Stenobracon*. From a number of *Stenobracon* pupae collected in the field it was observed that two of them were pale brown in colour as against the normal pale white healthy cocoons. From one of these cocoons, 8 female and 3 male hyperparasites emerged.

This is the second record of another species of hyperparasite on this beneficial parasite. As the hyperparasite is highly prolific, the authors feel that the discovery of this hyperparasite on *Stenobracon* emphasises the need for examining the material more carefully before introducing the parasite in the field. Narayanan, Subba Rao and Ramachandra Rao (1956) have studied a remarkable parasite complex in the larva of *Hymenia recurvalis* Fabricius that is a pest of many irrigated vegetable crops. The larvae of this pest is attacked by three primary parasites of which a species of *Apanteles* is the most abundant. From several of the *Apanteles* pupae emerged a series of hyperparasites belonging to the families of Elasmidae, Miscogasteridae, Eurytomidae, Encyrtidae, Eulophidae and Pteromalidae (Chalcidoidea : Hymenoptera) and a Calliceratid (Proctotrupoidea : Hymenoptera). It was also remakable that from each pupa only one particular species of hyperparasite emerged. In other words there was no multiparasitism in this remarkable phase of hyperparasitism. This phenomena of hyperparasitism shows how extremely complex is not only the pest-parasite relationship but also the parasite-hyperparasite association. Could it be that this occurrence is only a way to keep the balance of population in nature? There is a wide field for research in this direction which I have no doubt will attract some of the younger and energetic entomologists in our country.

NUTRITION IN INSECT PARASITES

There is a wide gap in our knowledge of the role of nutrition in parasites. There is little doubt that the use of parasites and predators is becoming a well established method of insect control and when this is so, every aspect of the study of parasite behaviour should take an economic and biological importance proportionately and not the least important of these studies is the role of nutrition in parasites. Many Hymenopterous parasites feed on extra floral nectaries of Umbelliferous flowers and they feed on the nectar of other flowers, as well. This is also true of many other wasps belonging to the order Hymenoptera. The presence or absence of these blossoms can sometimes determine whether a parasite can be successfully introduced in a locality or not. Thus Wolcott (1939) observes that the successful introduction and establishment into Puerto Rico from Brazil of a large wasp *Larre americana* Saussure, which is parasitic in its larval stage on the mole-cricket *Scapteriscus vicinus* Scudder depend on the presence in Puerto Rico of the two weeds *Borreyia verticillata* and *Hyptis atrorubens* from whose flowers the wasps obtain their nectar. When the weeds are not in flower the wasps decline in numbers and eventually perish. Does this feeding on the nectar which is nothing but sucrose solution and the corresponding increase in longevity anything to do with its power of prolificacy to lay a greater number of eggs? If this is so then it is an important factor that would govern the successful introduction and establishment of a parasite in a locality. It is also known that many Hymenopterous parasites of the families Chalcidae, Braconidae and Ichneumonidae feed on the blood of the host and it is presumed that protein food of this kind is necessary for the maturation of the eggs. There is, however, very little experimental evidence to prove this in the case of parasites. If this is actually so it has to be found out whether this nitrogenous food could be substituted by ordinary proteins such as milk, egg extract, yeast etc. A knowledge of this would greatly facilitate the laboratory multiplication of the parasites. There can be little doubt that a knowledge of the role of nutrition in parasites should be regarded as a key to the successful introduction, multiplication and establishment of parasites from one country to another or from one part of the country where they are abundant to other parts of the same country where they are scarce or are not found altogether.

The effect of feeding parasite on its longevity and fecundity has been studied in great detail in *Trichogramma evanescens minutum* Riley by Narayanan and Mukerji (1955).

HOST SELECTION

One of the most intriguing but nevertheless important problem in insect parasitism is that of host selection. The problem of host selection is of profound significance to the economic entomologists as the successful introduction and establishment of parasites in the biological control of insect pests will depend upon a proper understanding of this intricate phenomenon in insect parasitism. As Salt (1935) observes "every parasite has a number, one or more, of host species which it will attack. The inclusion in this number of some species and the exclusion from it others implies a process of selection on the part of the parasite which is usually known as host selection". It is a well known fact that within a chosen environment the parasite may find many animals that might serve as hosts, but of these it selects only certain ones suitable for attack. This theory, known as "host selection principle" clearly states that if a species is capable of feeding on three or more species, individuals tend to oviposit upon the kind in which they themselves developed. This theory had been the subject of much controversy and discussion. Narayanan (1954) carried experiments to find out the factors that govern the host selection of *Trichogramma*. These investigations have revealed some very important factors that govern host selection. The experiment was conducted with the eggs of different alternate hosts, namely, *Sitotroga cerealella* 01 iver., *Chilo zonellus* Swinhoe, *Gnorimoschema operculella* Zeller, *Corcyra cephatonica* Stainton and *Heliothis armigera Hubner*. It was found that strain of *Trichogramma* reared from *G. operculella* and *C. zonellus* preferred only *Gnorimoschema* eggs. These experiments have revealed that the size of the host eggs has got no significance in the matter of preference of the host. When two hosts are available simultaneously for oviposition, the distance between the adjacent host eggs has a considerable effect on the rate of egg deposition by the parasite. The shape of the host egg is also of no significance in the selection of the host. As revealed from the experiments the texture of the host eggs seem to be the dominant factor that governs the host selection of *Trichogramma*. It is also observed that as the host population increases, the efficiency of the parasite also increases. It is further observed that parasites reared from *Gnorimoschema* eggs are far more robust and healthier than the parasites bred on other alternate hosts.

Narayanan and Subba Rao (1955) studied in great detail the effect of different hosts on the physiology, development and behaviour and the sex ratio of *Microbracon gelechiae* Ashmead. They observed that the condition and availability of food material in the host influences the growth and formation of the ovaries of parasites bred on them. The number of ovarioles and their relative development in *M. gelechiae* is an important factor in assessing the fecundity. In the case of undernourished and under developed females the ovaries are reduced in size and in extreme cases the weak females have only one pair of fully developed ovarioles, the other pair being reduced. This finding is of extraordinary significance as it explains why the fecundity of several parasites bred from the same host varies so much. The developmental period of the parasite when bred on various hosts varied considerably ; the parasite took nearly 15-18 days on *Dichocrosis* larva as against the usual 10-11 days on *Corcyra* host to complete its development. The alfactometer experiments to test the selective behaviour of the parasites suggested that continuous breeding on an unnatural host for several hundred generations will affect the tendency of the parasite to select its original host. *Microbracon gelechiae* bred on *Scirpophaga nivella* Fabricius for four generations when tested for host preference in a modified McIndo's olfacto-meter did not show any preference to *S. nivella*. But *M. gelechiae* bred on *Corcyra cephalonica* Stainton for seven years continuously under controlled conditions, tend to develop into a distinct physiological race which shows preference to the new adopted host on which it was bred, even when the natural host *Gnorimoschema operculella* was available. The behaviour of parasites under the complex conditions of the natural environment may differ greatly from what is observed under artificial laboratory conditions. However, these results undoubtedly give some clue to the behaviour of the parasite bred on different hosts. These studies on the effect of hosts on the sex-ratio of the parasite have indicated that the size of the host, which has been considered by many workers as an important factor in the determination of the parasite, is not the sole or main factor. It was concluded that the final sex-ratio of the progeny of any parasite is mainly dependent on two important factors, (1) fertilisation, regulated by the spermatheca and (2) the influence of differential mortality on the developing larvae.

Snehamoy Chatterji (1955) studied the phenomena of host selection by the parasite *Aplastomorpha calandrae* (Howard) that parasitizes the larval and the early pupal stages of *Rhizopertha dominica* Fabricius, *Calandra oryzae* Linnaeus, *Bruchus analis* Fabricius and *Callosobruchus chinensis* Linnaeus.

ROLE OF GENETICS IN INSECT-PARASITISM

Practically no research work on the genetics of insect parasites have been carried out in our country. *Trichogramma* is one of those parasites that are mass bred in the laboratory and liberated in the field. In this case there is an enormous scope for the inbreeding of the parasite. This aspect of the problem, therefore, attracted the attention of Narayanan, Subba Rao and Ramachandra Rao (1956) and they studied the problem of selective breeding in *Trichogramma* in some detail. It was observed that the parasites that have been bred for a number of generations under laborotory conditions were inactive, malformed and did not lay the normal number of eggs. So it was thought expedient to introduce new blood. So a consignment of *Trichogramma* parasites were obtained from Mandya (Mysore) and these were crossed with the *Trichogramma* parasites in Delhi. This was done in two ways ; the male of Mandya culture was mated with the female of Delhi and the male of Delhi was mated with the female of Mandya. In both the cases the longevity and fecundity of the progeny was studied in detail by feeding with various sugars and polyhydric alcohols. There was a phenomenal increase in the fecundity of the parasite feeding on the sugars and sorbitol. Among the foods, no differences existed as regards their influenc on fecundity. A comparison of parent cultures and the reciprocal crosses regarding the longevity and fecundity gave very interesting results.

USE OF ATOMIC ENERGY IN INSECT PARASITISM

Within recent years advances in our knowledge of nuclear physics have opened an entirely new vista for enduring research work in biological problems. In the field of applied entomology the new technique developed in the use of the stable and unstable isotopes in one way or the other has helped entomologists to understand more clearly the chemical, physical or physiological processes taking place within the insect body. Radioactive isotopes are used as tracers by entomologists in different aspects of entomological research work. By the judicious use of the new technique it may be possible to increase the reproductive power of parasites and predators that play an effective role in the biological control of insect pests. Recently the effect of isotopically labelled compounds on the longevity and the rate of reproduction in a parasite of economic importance namely *Microbracon gelechiae* Ashmead has been started in the Division of Entomology, Indian Agricultural Research Institute, New Delhi.

TECHNIQUE OF MASS BREEDING OF PARASITES

In the biological control of insect pests the technique of mass breeding of parasites and predators in the laboratory on alternate hosts plays a vital role in the liberations and colonisation of these parasites and predators in the field.

Narayanan and Venkatraman (1952) standardised and perfected a technique of mass multiplication of *Stenobracon deesae* (Cameron) (Hymenoptera : Braconidae) for use against sugarcane and maize stem borers. *Corcyra cephalonica* was used as alternate host material and more than one host larva was used for the complete development of the parasite larva.

Narayanan (1948) developed and standardised the method of mass breeding of *Bracon gelechiae* Ashmead a prepupal parasite of the potato tuber moth *Gnorimosechema operculella.* The *Corcyra* larvae were used as alternate host but as the parasite would not lay eggs directly on the naked larvae a piece of muslin was interposed between the larvae and the parasites so that the cloth would simulate a pupal membrane.

Narayanan, Subba Rao, Angalet and D'Souza (1954) and (1956) standardised for the first time in the world a technique for the mass multiplication of *Apanteles angaleti* Musebeck. *Apanteles* is a larval parasite of many Lepidoptrous borers and does not ordinarily lay eggs under laboratory conditions. By adjusting humidity and by using *Corcyra cephalonica* as an alternate host the authors developed a perfect technique for the mass breeding of these parasites.

Subba Rao (1955) developed a technique for the mass breeding of *Microbracon chinensis* Szepligeti a parasite of the stem border of sugarcane and maize.

BIOLOGICAL CONTROL OF INSECT PESTS

The biological control of insect and plant pests is a natural sequence to the occurrence of insect and plant parasitism in nature. Of the six principal methods of insect control, namely, the mechanical, the cultural, the physcal, the chemical, the biological and the legislative, the biological control of insect pests or sometimes described as the biological basis of insect control has attracted much attention within recent years. As Munro (1931) observes, "In the main the reasons for this are the astonishing successes of the late Dr. Muir in his Hawaiian work and the strong championship of parasites as controlling agents by Dr. Tillyard in Australia. The establishment at Farnham Royal of the Parasite Station of the Imperial Institute of Entomology has made control of noxious insects by parasites of special interest to the Empire, and the remarkable results recently obtained by Messrs. Tothill, Paine and Taylor in the control of the Levuana moth in Fiji by the Tachinid parasite *Ptychomyia remota* Aldrich have further added to the popularity of this method. "A much earlier and a more spectacular troumph than the Hawaiian introductions, a critical summary of which has been published by Imms (1926), was the introduction in 1899 of the Cocoinellid beetle *Rodolia cardinalis* Mulsant from Australia into California to subjugate the fluted or cottony cushion scale *Icerya purchasis* Maskell. Accidentally introduced into California from Australia or New Zealand through imported plants and bereft of the restraining influence of its natural enemies that kept the pest under check in its native habitat, the scale multiplied with such alarming rapidity that it threatened the orange and lemon groves of that state with extinction. Alfred Koebele of the United States Department of Agriculture was sent to Australia to find out if possible any natural enemy of the pest in its native home. As Howard (1930) puts it "the results of Koebele's work are now known every where. The story has become a classic in Applied Entomology and Horticulture." The small lady-bird beetle *Rodolia cardinalis* was introduced and the Coccinellid silently but effectively brought about such an appreciable reduction of the pest that it was no longer a menace.

Though these early successes created a vogue in parasite control, yet there are other reasons as well why the biological basis of insect control has been recognised by entomologists all over the world as an important weapon at the disposal of the economic entomologist. Mechanical and chemical control such as spraying, fumigation etc., are either unsuitable in certain localities or are not always an economic proposition. Moreover they have to be repeated year after year. Further as Thompson (1930) observes "they do not bring the population level of the pest low enough to prevent a recurrence or even an increase of damage in the following year. In certain parts of the world the amount of arsenic now used during the ordinary treatment against the Codling moth in apples, is so great that the arsenical residue on the fruit at the time that it is gathered is dangerouly large and has to be removed by special processes. There is some reason to suppose that the arsenical compounds washed down into the soil may, after a certain length of time, prove injurious to vegetation. Furthermore, in some cases at least, there is definite evidence that certain species of injurious insects are becoming immune to some of the poisonous substances ordinarily used, such as hydrocyanic acid gas and lime sulphur wash". There are also technical difficulties such as the availability at the required time and place a team of personnel trained in the science and practice of using lethal insecticides. In cases like these the biological method of control offers a very promising and economical method of attack. I shall now very briefly describe some of the more important experiments and trials that have been carried out in our country against insect pests of agricultural crops and noxious weeds.

The earliest experiments in biological control were carried out against the spotted boll worms *Earias fabria* Stoll and *Earias insulana* Boisduval in Gujarat in the early twenties by liberations of *Rhogas testaceous* and *Microbracon lefroyi* D & G. These experiments, however, were not conclusive even though the infestation of the boll worms had gone down to some extent. (Deshpande & Nadkarny, 1936).

Consignments of the parasites of the Wooly apis *Eriosome lanigera* Hausmann, *Aphlinus mali* Haldeman were introduced into the Kulu valley where they effectively controlled this serious pest (Khan A. Rehman, 1940). This chalcid wasp spread to the Kashmir valley and during my survey of the parasites of the San jose scale in Kashmir valley in 1951 I found the parasites doing excellent work.

Narayanan (1933) in a paper suggested the colonisation of *Trichogramma* parasites in the sugarcane growing tracts to control the sugarcane stem borer. Later in a scheme financed by the Indian Council of Agricultural Research, the biological control experiments were planned on an all India basis. Narayanan and Mukherji (1953) have given an account of the field trials carried out in eight centres. Exploratory field trials and experiments proved that the parasite was beneficial at Madras, Orissa, Bihar and Bombay, where the damage caused by the borers was checked to an appreciable extent resulting in an increase in the yield of cane. However, the data obtained from other centres were rather erratic and could not be made use of for any definite conclusion. Ramachandra Rao and others (1948) studied the possibilities of controlling the cocoanut caterpillar *Nephantis serinopa* Meyrick by its natural enemies. The habits and their way of attacking the host are briefly discussed. Amongst the many parasites that were studied the Eulophid *Trichospilus pupivora* Ferriere was found to be the most efficient. This parasite was introduced to Mangalore and Coimbatore from Cochin. The results however were not conclusive, though they certainly brought about a decrease in the damage.

Narayanan (1948) has discussed the possibilities of controlling the Rice stem borer *Schoenobius incertellus* Walker and the maize stem borer *Chilo zonellus* Swinhoe by means of their natural enemies. Subramaniam (1954) gave an account of the biological control of the fluted scale *Icerya purchasi* Maskell in different states which included Coorg, Mysore, Travancore, Bombay and Madras. In most of the centres the lady bird beetle *Rodolia cardinalis* Mulsant was released on a large scale to check the pest.

Though we have not achieved so far spectacular successes in the biological control of insect pests the biological control of noxious weeds has yielded some excellent results. Ramakrishna Ayyar (1931) states that the introduction in 1795 by Captain Neilson of the mealy bug *Dactylopius indicus* Green to check the spread of the prickly pear, *Opuntia monocantha* Haw. was a great success and that the introduction of the wild cochineal *Dactylopius tomentosus* Linnaeus from Ceylon to exterminate another prickly pear, *Opuntia dillenii* Haw. covering large areas of arable land and causing untold nuisance to the peasantry, has met with remarkable success in southern India.

Lantana camara is a very serious noxious weed covering hundreds of thousands of acres of arable and pasture land in our country. Subramaniam (1934) recorded *Agromyza lantanae* Froggot an introduced fly from Hawaii for the control of *Lantana camara.* The fly had established itself in the Mysore state inspite of unfavourable climatic conditions. The control effected by the fly, however, was not appreciable at all. Preliminary experiments carried out by the Forest Research Institute (1944) under quarantine by importing the lantana bug *Teleonemia scrupulosa* Stal. showed that the bug also fed and developed on teak wood leaves and inflorascence. Seeing grave danger in the colonisation of the bug in *Lantana* areas to teak wood forests the project of introducing and establishing this bug was abandoned.

There is a vast field for further research and experimental work in biological control in India. Of all the countries of the West the United States of America alone has made tremendous advance in this branch of insect control. But then during the last sixty years the entomologists of America have carried out a world wide search for beneficial parasites and predators and they have practically combed every country that lay in the temperate, sub-tropical and tropical zones. This search is still going on. Let us sincerely hope that with the establishment of the sub station of the Commonwealth Institute of Biological Control at Bangalore greater impetus will be given to this method of insect control.

Future Work

I shall now devote some space in my address to future work in our country on this specialised branch of entomology, certain aspects of which I have unfolded before you to day. The age that we live in is an age of science and technology and if we have to maintain our position among the great nations of the world we have to keep abrest with them if not of them in our scientific advance. The job of an entomologist is to control insect pests of crops and all the research work that he carries out in the laboratory and in the insectary must inevitably centre round this main objective. The last decade and a half will ever be remembered in the annals of applied entomology as the period when some of the most powerful insecticides ever known to man were discovered. Yet the DDT, the Gammaxene, the organo phosphorous compounds and the other chlorinated hydrocarbons though solving some problems have also created new and more difficult problems. As Leyland Cole (1950) observes, "Although even today the food crops treated against insect pests are only a small fraction of the total protection, the increasing use of insecticides mostly more or less toxic to man has raised querries about their effect on health". As Munro (1929) observes, "Insecticides as a class are palliative measures bringing about a more or less rapid decrease of the pests during the first or second seasons of its abundance". Wigglesworth (1950) goes a step further when he says, "By all means let us use insecticides when we can do no better. But we should regard them as C. B. Williams has emphasised more than once as an admission of failure to be replaced by the more subtle and more remunerative methods of biology as soon as these can be worked out". There can be little doubt that the biological basis of insect control is certainly one of subtle and remunerative methods. Of this method Munro says "More fundamental in its application is the control measure termed 'parasite control' ". But the introduction and establishment of parasites from one country to another is no easy matter. Again as Munro (1929) remarks, "It must in fact be admitted that some of the early successes in parasite introduction were largely fortuitous and we realise today that the chances of successful introductions are not always good but on the contrary failures should be frequent." If failures are to be avoided, if parasite introductions should be successful, there should be sustained research, more and more research to probe into every aspect of the problem. Let it be remembered that this sustained research is worth while ; for the biological method offers a very promising and economical method of attack. In this matter let us follow the Canadian example. When I visited Canada in the summer of 1955 the new three storey Biological control laboratory at Belleville Ontario had just been completed. This fine new laboratory built at a cost of about two million dollars and which is exclusively meant for biological control research and which is the largest of its kind in the world replacing the former Dominion parasite laboratory represents an act of faith on the part of the Canadian Department of Agriculture in the biological basis of insect and weed control in an age when organic insecticides and weedicides rule the mind of entomologists all over the world.

I shall now briefly discuss some of the lines of work that we should initiate and intensify in our country on the fundamental and applied aspect of this fascinating problem. First : We have to intensify the work on the taxonomy of parasitic Hymenoptera. It has already been mentioned before that "The Hymenoptera are the dominant among the entomophagous insects". I am of opinion the Indian Council of Agricultural Research should entrust some of the taxonomic entomologists of our country with the preparation of the Fauna volumes of some of the more important families like Chalcidoidea, Braconidae and Ichneumonidae to start with. This work later on should be extended to other families like the Bethylidae, Dryinidae, Evaniidae and others.

There is a gap in our knowledge of Indian Tachinids and taxonomic research work on this family should also be initiated at an early date. Tachinid flies are economically very important as many members belonging to this family select as their hosts many lepidopterous larvae that are serious pests of agricultural crops. They also select as their hosts larvae of Coleoptera, Orthoptera and Hemiptera. Taxonomic research on Coccinellidae should also be initiated. Within recent years a number of excellent parasite-host catalogues have been issued by Dr. W. R. Thompson, F.R.S., (1943-53) of the Commonwealth Institute of Biological Control. The list of parasites however, is incomplete in many cases as far as as the Indian Union is concerned. There should be a concentrated effort to bring these catalogues up to date which can be done only by the intensive survey of the insect parasite fauna of the Indian Union. A beginning in this direction has been made in the Indian Agricultural Research Institute, New Delhi under a scheme in the Second Five-year Plan.

Second : Fundamental research work on the embryology and histology of insect parasites should be initiated not only in the various central Institutes but also in the Universities as well for a proper understanding of the host parasite relationship in the case of endoparasites.

Third : Insect genetics in relation to parasites has been totally neglected in our country so far. We have made a beginning on this aspect of study in the Indian Agricultural Research Institute. Research work on this problem has to be intensified. These studies will help in getting segregates of parasites that show resistance to insecticides and also help us in evolving hybrid stocks of parasites that have greater longevity and fecundity.

Fourth : The utilization of radio active isotopes to study the behaviour of parasites and predators should be intensified. As mentioned earlier a beginning has already been made in this direction in the Indian Agricultural Research Institute, New Delhi.

Fifth : Research work should be started at once on the possibility of controlling insect pests by pathogenic organisms. A survey should be made in our country of the micro-organisms associated with some of our insect pests. Organisms found in dissected samples will provide us with information on some of the characteristics of pathogenecity, host-resistance etc.

Sixth : We must start at once a survey to find out the insect enemies of the two serious weeds *Xanthium strumarium* and *Carthamus oxyacantha.* This survey may reveal some insect pests of potential importance to control these plant pests.

On the applied aspect the following projects should be immediately undertaken under the auspices of the Indian Council of Agricultural Research.

First : The control of sugarcane borers in India is one of our chief problems and till now we have not evolved a satisfactory method of controlling these pests. It would be advantageous to import the Cuban fly *Lixophaga diatraeae* Towns. and the Amazon fly *Metagonistylum minense* Towns. In Louisiana these parasites have in some cases controlled the borers to an extent of 75%.

Second : The mustard aphis *Lipaphis erysimi* takes a heavy toll of the crop each year and in 1946 the mustard crop in U.P. and Bihar were almost completely destroyed by the mustard aphis. We may import some lady beetles and I would particularly recommend the introduction and establishment of the convergent lady beetle *Hippodamia convergens* (Guer).

Third : We should also introduce and establish the chalcid *Euplectrus platyhypenae* How. and the Tachinid *Archytas cirphis* Cur. from Hawaii to control the army worm, *Cirphis unipuncta,* which is a serious pest of rice and other cereal crops.

CONCLUSION

What we have achieved so far is but a minute fraction of what we have yet to know. It may well be asked by entomologists whether there is any use at all of attacking a problem that is far beyond our strength. But to the scientist it is sheer joy to hammer at the truth. He knows that only sustained and persistent endeavour will make nature yield her closely guarded secrets and for him there is both adventure and hope to traverse along this hard road sanctified by so many kindred spirits in the past like Linnaeus and Darwin, Copernicus and Galileo, Ramanujam and Jagadish Chandra Bose and many others.

For an entomologist it is however, well to remember Whitman's song of the open road:

> Now I reexamine philosophies and religions,
> They may prove well in lecture rooms,
> Yet not prove at all under spacious clouds
> And along the landscape and flowing currents.

Whatever we achieve in the laboratory would only be worthwhile if it enables us to comprehend and interpret the phenomena in the field which again is but a step in our efforts to solve the problem of our beloved and hard working peasants in their incessant fight against insect pests to protect their crops.

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SECTION OF PHYSIOLOGY

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SOME THEORETICAL AND APPLIED ASPECTS OF THE PHYSIOLOGY OF UNSTRIATED MUSCLE

Comparatively, more attention has been devoted by physiologists to striated than to unstriated muscle, though the disorders of former muscles are comparatively rare, when compared to those of unstriated muscle. We are ushered into this world by contraction of unstriated muscle. Disorders of the unstriated muscle of the alimentary canal and other tubular structures are common ailments. The modern stress and strain of life leads to the contraction of the unstriated muscle of the blood vessels, which in turn damages the kidneys and the heart, so that the problem of heart disease in coronary attacks is really the problem of blood vessels and their smooth muscle. Similarly, some disorders of the nervous system are due to vascular spasm, local and general.

Chemical composition of unstriated muscle : *significance of sodium.* There is increased interest in this subject in recent years owing to its relation to hypertension. It is now generally recognised that ionic imbalance results in hypertension. It has been shown that the substitution of hypertonic solutions of sodium chloride for the drinking water will cause an arterial hypertension[1] ; this hypertension is not mediated through the adrenal gland or the kidney.[2] In renal hypertension, there is increased concentration of sodium in various tissues.[3] Sodium therefore, appears to be related to hypertension in some way, and its action is peripheral.[4] The action of sodium on unstriated muscle is demonstrated in two ways : (1) The effect of sodium content of the muscle on its tone. (2) the effect of sodium on the contractile mechanism. Increased sodium content of the muscle is associated with increase in the tone.[5] Sodium causes contraction of the contractile mechanism by direct effect on its proteins.[6] Retention of sodium would therefore result in hypertension.

It is also possible that sodium content of the unstriated muscle of the blood vessels might increase as a secondary effect of hypertension due to some other cause, and make the hypertension permanent. The disappearance of the original casual factor will not result in the subsidence of hypertension, which will therefore become irreversible. Stimulation of unstriated muscle increases its sodium content.[7] Hypertension produced by infusion of nor-adrenaline results in increase of sodium content of some tissues.[8, 9] The increase in the sodium content of unstriated muscle would be a consequence of increased permeability following excitation of the muscle.[6, 10] Thus hypertension started by adrenaline or nor-adrenaline, renin, or vasomotor nerves may not subside after the withdrawal of the original stimulus or disappearance of these substances from the blood stream.

Decrease in intracellular potassium and increase in intracellular sodium also increases excitability of unstriated muscle and the nervous system.[6] Hypertension then might result due to increased sensitivity of the blood vessels, or to increased tone of the vasoconstrictor centre or higher centres.

Significance of potassium. Intracellular potassium, besides being a suitable medium for the actomyosin system of the muscle, also maintains the normal excitability. Changes in concentration of potassium inside the fibres can be produced by changing the osomotic pressure of the medium.[5, 11] Changes in osomotic pressure, and hence changes in the concentration of intracellular potassium, affect the phasic response and tone differently.

There are two kinds of tone ; one kind is increased and the other decreased by increase in osmotic pressure of the medium. Hence intracellular potassium increases one kind and decreases the other kind of tone.[12] Further experiments now being conducted in our laboratory show that for one kind of tone, an optimum concentration of potassium is necessary inside the cells. Increase or decrease beyond this optimum limit decreases tone. This would account for the varying effects of potassium on hypertension. Thus potassium retention in adrenal insufficiency decreases blood pressure, though this may also partly be due to sodium loss. Potassium depletion also, causes fall in blood pressure.[13]

The effect of extracellular potassium is variable. Decrease in such potassium might increase or decrease tone.[7, 14] In the intact animal, therefore, the picture is complicated, and several variables have to be taken into account to determine the cause of the changes in blood pressure as a result of potassium deprivation or retention.

Potassium has a relaxing effect on the contractile mechanism of unstriated muscle,[15, 16] so that the fall of blood pressure due to retention of potassium is likely to be due to this effect.

Intracellular potassium has another important function in promoting the contractility of muscle. The phasic and spontaneous contractions of unstriated muscle are related to the intracellular concentration of potassium.[14, 17] Potassium acts on the contractile mechanism of unstriated muscle in a way very similar to its action on actomyosin.[18]

Significance of calcium. Intracellular calcium would be responsible for accommodation or adaptation of muscle.[19, 20] Calcium also causes contraction of the contractile mechanism.[15] As there is a natural increase of lime salts in the arteries of the aged, this action of calcium might be responsible for the physiological increase of blood pressure with age. Calcium also causes extrusion of sodium.[5]

Excitability. Unstriated muscle can be stimulated both electrically and chemically, but in some unstriated muscles, the properties of these two types of responses differ whether they be inhibitory or excitatory.[7, 14, 21, 31] In these muscles, therefore, it is possible to decide whether a particular response has been produced by electric current or a chemical substance. The application of this finding can be used to decide between the electrical and chemical theory of nerve transmission in certain situations. It is possible to say therefore, whether a particular response has been produced by the action potentials of the nerve or by some humoral substance secreted by it.

Experiments on the nerve-smooth muscle preparations of dog's and frog's stomach suggest that the action of the vagus nerve is produced by secretion of acetylcholine, and also by the action potential of the nerve, as the response produced by nervous stimulation resembles that produced by a chemical substance as well as by electric current.[22]

The effect of ions. The effect of various ions on unstriated muscle is well known. A somewhat different behaviour of some unstriated muscles is their ability to preserve their excitability in the absence of sodium, or even all electrolytes. Overton[23] found that the frog's striated muscle becomes inexcitable in a few minutes if it is immersed in an isotonic solution of sucrose. Frog's stomach muscle does likewise, but if the osmotic pressure of the sucrose solution is reduced by half, then after an initial depression the muscle recovers and remains irritable for several hours.[24, 25] Reduction of osmotic pressure dilutes the intracellular fluid containing potassium, so that excess of potassium inside the fibre is toxic, just as it is toxic outside the cells. It appears, therefore, sodium outside the fibres neutralises some action of potassium inside. In the presence of sodium, the cell can withstand higher concentration of potassium inside the fibres. Similarly, the action of ions outside the cell is balanced by those inside, as shown by the fact that the toxic effect of extracellular potassium can be overcome up to a certain extent by increasing the concentration of intracellular potassium by raising the osmotic pressure of the medium.[7]

The action potential of nerve has been explained on an ionic basis.[26, 27] Owing to recent interest on the action of sodium on exitability, Dr. J. V. Bhatt and myself have reinvestigated the effect of sodium free solutions on unstriated muscle. We have used four different solutions. The first solution is approximately half tonic sucrose (0·112 M). The second one is made by adding a little potassium to the half tonic sucrose, giving a concentration of 0·0006 M to 0·003 M KCl. The third is made by adding a little calcium to the second solution (0·0001 M to 0·001 M $CaCl_2$). The fourth one is made by replacing all the sodium of the saline with potassium.[28] The muscle remains irritable for several hours if the sodium of the saline is also replaced with lithium, ammonium, magnesium, calcium and strontium.

The muscle remains irritable for over 20 hours in such solutions to direct current, especially the break of it, to adrenaline and acetylcholine. It even becomes hyperirritable, so that the spontaneous contractions may be several times longer in the presence of sodium than in its absence. One may argue that this merely a diffusion effect, the lingering excitability in the absence of sodium might be due to slow diffusion of sodium outwards. This is not the case, as shown by the fact, that if the muscle has acclimatised to a half tonic sucrose solution, it will become absolutely quiescent on reimmersion in sodium saline, and take time to acclimatise to sodium. When the muscle is contracting strongly, chemical analysis shows that it does not contain any significant amount of sodium.

Action potentials can be recorded from the muscle in hypotonic sucrose solution. This shows that no electrolyte is necessary in the external medium for the production of these potentials.

Action of cholesterol. Cholestorol is deposited in the intima of the blood vessels in atheroma. The muscular coat may also contain it in excessive amounts, as there is no liklihood of any diffusion barrier between the intima and the other coats of the blood vessels. The question arises whether cholesterol acts as an inert substance, or whether it can cause tonic cotraction of the arterioles. Cholesterol appears to cause constriction of blood vessels.[32]

This finding is of importance, as it would explain coronary attacks in the absence of sufficient atheromatous changes if there is hypercholesterolaemia. It would also explain the incidence of coronary attacks which occur after a meal. After a meal, there may be a rise in the lipoid, hence the cholesterol content of blood, and this may precipitate an attack.

Metabolism of unstriated muscle. Metabolism in unstriated muscle usually follows the pattern found in striated muscle, but there are important exceptions. Unstriated muscle shows two types of contractions.[30] One kind of response is accompanied by increase and the other by decrease in lactic acid production. The oxygen consumption also shows similar variations. Corresponding to this there are two kinds of relaxation, one being followed by increase and the other by a decrease in the production of lactic acid or oxygen consumption. It is clear, therefore, that we are dealing with two contractile systems in this muscle, in one the relaxation being active and in the other, passive.

Corresponding to the above, it has been found that asphyxia or cyanide might decrease or increase tone, and glucose and oxygen similarly, might have a dual effect. The decrease of the mechanical response, when there is increased expenditure of energy by the muscle, means only one thing, that is, the muscle is simultaneously relaxing actively while it is contracting. Thus both contraction and active relaxation of the muscle may be triggered simultaneously, and hence account for the absence of heat production during relaxation.

There are other experiments which point to active relaxation in unstriated muscle.[33] For these experiments, frog's stomach muscle is used. The muscle is used unloaded, freely floating in saline in a petri dish. At first adrenaline is added. The muscle relaxes. The muscle is then immersed in saline containing sodium cyanide. Adrenaline now produces no effect. The muscle is then immersed in saline containing cyanide and glucose. Adrenaline again produces relaxation. This effect of glucose is abolished by iodoacetic acid. These experiments leave no doubt as to the active nature of relaxation in certain unstriated muscles. As mentioned below, this is further shown by the fact, that unloaded dead muscle also relaxes under certain conditions.

A convincing example of active relaxation has been found to occur in retractors of the introvert of the marine worm Phascolosoma. The unloaded muscle, after stimulation of the brain relaxes with great speed by 100-200 per cent of its length before stimulation.[34] Rabbit's gut muscle, which is very sensitive to adrenaline, if stretched, does not relax at all when unstretched. Therefore, there are two kinds of relaxation, one active and the other passive.

These two kinds of relaxation can be differentiated by the action of substances which suppress metabolism. Thus sodium cyanide, iodoacetic acid, sodium azide, decrease active relaxation but increase passive relaxation.

Antagonism between active and passive relaxation of muscle. These two kinds of relaxation are antagonistic.[35] This is shown by the fact, that in certain solutions, the muscle relaxes more if unloaded, than if it is loaded. This is due both to the excitatory and the contractile mechanisms, as it is also shown by muscle, in which the excitatory mechanism has been destroyed by heating.

The existence of two systems in some unstriated muscles can be shown directly.[36] Thus if the unloaded heat-killed muscle is heated to 60-70°C., then it relaxes. The supply of energy to the contractile mechanism thus causes active relaxation. If once the muscle is heated to 70°C., then active relaxation is permanently inactivated. It now gives a contraction which is proportional to rise in temperature, and the relaxation is passive. The supply of energy to the contractile mechanism, therefore, now causes proportionate contraction. In some muscles, therefore, both contraction and relaxation are energised.

It is interesting to note that if the muscle is once heated to 70°C., then reheating to any other temperature from room temperature, now causes a bigger response than before inactivation of the relaxation.[37] This therefore supports the idea mentioned above that a diminished mechanical response under certain conditions, such as by glucose or oxygen, may be due to simultaneous active relaxation.

The relation between muscular contraction and denaturation of proteins. Denaturation of protein is supposed to consist of an alteration of the specific internal structure of the protein wherein the closely folded peptide chains unfold. Similarly, the contraction of muscle is supposed to be due to folding of the contractile protein ; so relaxation would be due to unfolding of the muscle proteins. Thus process of relaxation of muscle would be similar to the denaturation of proteins. The similarity between the process of relaxation and the denaturation of proteins is shown by the fact that many agencies both physical and chemical, which denature proteins also cause active relaxation of heat killed unstriated muscle.[38, 39]

In the mechanism of enzmatic hydrolysis, it is presumed that the proteolytic enzyme at first denatures the protein. This action of the enzyme can be tested on the heat killed unstriated muscle.[40, 41] It has been found that active relaxation is produced by trypsin and papain, but not by pepsin. In the case of pepsin, the active relaxation is produced by the hydrochloric acid medium. These experiments therefore indicate that hydrolysis of proteins by enzymes is preceded by unfolding of the polypeptide chains. This might be done by the enzyme itself, or by the medium in which the enzyme acts.

Tonus in unstriated muscle. During tonic contraction it may be presumed that the unfolding of the polypeptide chains, is prevented by the development of cross linkages between the chains. The nature of these linkages can be ascertained by treatment of the heat-killed muscle with various reagents. There appear to be at least three types of such bonds : (a) hydrogen bonds, (b) S-S linkages. (c) salt linkages. The presence of hydrogen bonds is shown by the active relaxation produced by urea, distilled water and heat. The presence of s-s linkages is shown by the active relaxation produced by sodium cyanide, sodium sulphide and sodium sulphite. Salt linkages are indicated by relaxation produced by salts.

One kind of tone in unstriated muscle can be mechanically destroyed without affecting the phasic response.[42, 43] The lateral bonds are thus mechanically ruptured. The phasic response shows that the folding of the polypeptic chains remains unimpaired. It is difficult to conceive of normal folding of the polypeptide chains when some of their lateral branches have been destroyed by such a procedure as sudden stretching. It is therefore reasonable to assume, that the phasic response is produced by a different set of polypeptide chains. In the muscle, therefore, there appear to be two sets of polypeptide chains, one for phasic and the other for tonic contraction. It is possible that the tonic mechanism relaxes actively, as the rupture of cross linkages chemically results in active relaxation. This is also shown by the fact, that this kind of tone is unaffected by asphyxia, and results in diminished production of lactic acid and decreased consumption of oxygen.

Unstriated muscle, however, shows a second kind of tone, the mechanical reduction of which also reduces the phasic response.[44] This kind of tone therefore is produced by the same system of polypeptide chains, which fold to produce the phasic response. This kind of tone is reduced by asphyxia, and is accompanied by increase in the production of lactic acid and increased oxygen consumption. But in this system also, the polypeptide chains can be maintained in folded condition by the development of cross linkages, as in *Mytilus* muscle, both the phasic and the tonic responses are reduced by mechanical disruption, but the tone is not affected by asphyxia.[45] In this system relaxation appears to be passive.

The heat-killed muscle responds with greater tension if the initial length is increased. This phenomenon in living muscle is therefore partly due to changes in the contractile mechanism. The basis of the Starling's law of the heart therefore lies in the contractile mechanism.[46]

The action of ions shows, that there are at least two kinds of contractile mechanisms in unstriated muscle.[49] Frog's and dog's stomach muscle has one kind, and *Mytilus* muscle, the other. The contractile mechanism of *Mytilus* muscle resembles that of striated muscle.[50]

Permeability of unstriated muscle. The permeability of unstriated muscle to the monovalent ions varies in the order

$$Li<Na<NH_4<K$$

and to an ions, the order

$$C1<Br<N0_3<I<SCN<CN.$$

The stimulating power of these ions also varies in the same order.[5, 47] Calcium appears to cause extrusion of sodium.[5] This might be concerned in the mechanism of absorption and secretion of electrolytes by cells. On the absorbing side, there would be diminished concentration of calcium. On the secreting side of the cell, the arrival of the electrolyte might liberate calcium, which in turn might extrude the electrolyte.[47]

Excitation by electrolytes appears to be produced as a result of difference in concentration of ions on two sides of the muscle membrane. When the idons diffuse into the cell, this difference in concentration is equalised, and the contraction subsides. On withdrawal of the electrolyte, the increase in concentration of the ion inside the cell, produces another contraction.[12, 14] These experiments support Straub's theory of drug action. It follows therefore that an ion to which the muscle is permeable will neutralise a contraction produced by an ion to which the muscle is comparitively less permeable.[48] Thus the contraction produced by sodium and barium in *Mytilus* muscle is neutralised by ammonium or potassium.

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SECTION OF PSYCHOLOGY AND EDUCATIONAL SCIENCES

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PLACE OF PSYCHOLOGICAL TESTS IN VOCATIONAL GUIDANCE

I should express, at the outset, my deep sense of gratitude for the great honour you have done me by electing me as the president of this Section of the Indian Science Congress. I seek your permission to utilize this opportunity for sounding a note of warning to the rising generation of Indian Psychologists in discharging an obligation which is of paramount importance in the context of the country's bid for national reconstruction. I am afraid that my observations may cause disillusionment to some and chill the enthusiasm of others. I think I would be failing in my duty as a psychologist if I refrain myself from giving a free and frank expression to my feelings regarding a matter which is vital for the proper growth of psychological service in this country.

The aim of vocational guidance, as enunciated by Super[1], "to facilitate the smooth functioning of the social economy through the effective use of man-power" is highlighted by the impetus given to the vocational guidance movement in modern India under the impact of the National Development Plan. From the modest position of a process of 'helping people make good vocational adjustment', it has been elevated to the rank of a nation building service. As a result, we have witnessed, within a short period of two or three years only, a progressively increasing growth of vocational guidance centres, run on governmental or non-governmental basis. Ever increasing demands are being made by these centres on the development of tools and techniques for use in guidance service. Lack of adequate measuring instruments for assessing the potentialities of persons seeking vocational guidance is keenly felt. High pressure is put on the agencies working on psychological tests to cope with the demand. Self-styled psychometricians and inexpert test technicians are mustering strong to prepare and supply ill-conceived and poorly designed test materials.

The glamour for psychological tests and the unflinching faith in their unlimited possibilities as instruments of guidance were very well illustrated at the joint meeting of the Working Conferences of Educational & Vocational Guidance in Multipurpose Schools and of Research in Training Colleges in India, held at Ootacamond last June. The guidance workers gave expression to their utter helplessness in furthering the guidance programme unless aided by the training college researchers through a constant supply of skilfully designed and constructed measuring instruments. The training college experts regretted their inability to deliver the goods since their preoccupation with their professional obligations did not spare them time and energy to devote to the development of psychological tests. Both groups parted with a bitter taste in their mouth and it seemed that the prospect of guidance service was doomed in this country.

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[1] Super, D.E., Appraising Vocational Fitness, p. 1, Harper & Bros., New York.

Reports on the work of the vocational guidance centres operating in the country are saturated with accounts of test administration. Tests of intelligence, aptitudes, interests and personality, of all varieties, are being abundantly used either in their original occidental forms or just translated in the local languages. Even the Rorschach has been drawn into the vocational testing service.[2] Scoring keys and norms worked out on American or English samples are uncritically accepted and utilized for interpretation of the scores made by the testees. The results thus obtained are used, with or without other evidence, in planning the educational and vocational programmes of persons coming to seek guidance from the 'experts'.

It appears that the attitude toward vocational guidance as synonymous with vocational testing that dominated American psychologists in the early stages of the movement, characterises the approach of most phychologist, as well as the lay intelligentia, to vocational guidance in this country. It is high time that we call halt and pose the following questions : 'Is test administration and analysis the sine quo non of an effective vocational guidance service'? 'Does the major professional responsibility of a vocational counsellor terminate with an elaborate and organised psychometric test programme'? 'Should the activities of a guidance worker be confined to the areas of fact finding, test analysis and occupational information'?

MEANING OF VOCATIONAL GUIDANCE

What precisely do we mean by vocational guidance? Vocational guidance has been defined in diverse ways in the literature. But there is one aspect of the guidance process regarding which there is little disagreement. It is a process of helping people, young and old, with their vocational problems. It is a kind of service rendered to the individual by assisting him in getting at a comprehensive understanding of himself and of the relevant facts about the world of work in order that he might plan for himself a vocation that brings him the experience of maximum success and satisfaction. "Guidance is not direction. It is not the imposition of one person's point of view upon another. It is not making decisions for an individual which he should make for himself. It is not carrying the burdens of another's life. Rather, guidance is assistance made available by competent counsellors, to an individual of any age to help him direct his own life, develop his own point of view, make his own decisions, carry his own burdens".[3] Vocational guidance is calculated to develop in the client the capacity to mobilise and integrate his own resources in relation to the occupational opportunities of the environment so that 'he may live and make a living to the best advantage to himself and to society'.

Super[4] has divided a vocational guidance programme into two parts: (1) diagnosis and (2) therapy or counselling. The vocational counsellor uses all his technical skill for the analysis and interpretation of the potentialities of his client—his assets and strengths. He collects all relevant facts about the client's abilities, aptitudes, interests, attitudes, inclinations and the various types of influences that act upon him, and interprets these facts in relation to the occupational opportunities that the environment offers him. In other words, the vocational counsellor attempts at achieving a comprehensive understanding about the client which he integrates with the knowledge and understanding that his professional training and experience place at his command about the world of work. This process of matching the facts about the client—'the psychological data'— with the facts about occupations—'the socioeconomic data'—constitutes the diagnostic aspect of vocational guidance.

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[2] Guidance work at Dehra Dun, Manava Bharati, Vol. 1, 2 August, 1956, p. 3.

[3] Crow, Lester D. & Crow, A. An Introduction to Guidance Principles and Practices, p. 6, American Book Co.

[4] Super, D.E., op. cit., p. 2.

Some guidance workers stop at the diagnostic phase of the guidance programme and recommend to the client a vocational plan that in their judgment is most appropriate to him. They leave it for the client to accept or reject the plan. Others may be more considerate and use the method of pursuasion to the end that the plan is accepted and decision is taken in accordance with it.

The vocational plan has a meaning for the counsellor since it brings him the psychological, if not only the administrative, satisfaction of having done a 'good job'. But the plan may have no significance for the client. Its acceptance may have been thrust upon him instead of being inspired by genuine self-understanding. It may be far short of being in accord with his attitudes, his urges and his feelings, though he may have achieved an intellectual understanding of its soundness and logical cogency. He may choose the career thus prescribed and enter upon it. But being out of harmony with the undercurrents of his existence and the still unaltered concept of his self, the career he embarks upon does not infuse him with the spirit of self-identification from which alone stem the real passion and enthusiasm for one's understandings, without which job adjustment in the psychological sense remains an unrealised goal.

The diagnostic approach strikes at the surface of the client's personality and may or may not find its echo in his needs, drives, urges and aspirations. The aim of counselling is to touch the dynamics of the personality and thus work its way into the process of the client's motivation. It does not aim, primarily, at the formulation of a vocational plan, but strives for its acceptance in a manner that is the outcome of genuine self-understanding. Instead of weakening the client's ego by urging him to resign to the occupational choice dictated by the diagnostic findings, counselling aims at developing ego-strength by assisting the client to mobilise his resources uncovered through the process of self-revelation. The diagnostic phase of guidance prescribes optimal adherence on the part of the client to the routine processes of testing and fact finding. He is required to assume a typically passive role. Counselling, on the other hand, prepares the client for active participation in appreciating his vocational problems and working out his own vocational choice which is likely to bring him optimal success-one that points to the right course not only in the counsellor's view but also from his own standpoint. Counselling concedes to the client his right of self-determination and self-direction, warding him off, at the same time, against the hazard of exercising this right blindly or arbitrarily.

PSYCHOLOGICAL TESTS

"A psychological test is a pattern of stimuli selected and organised to elicit responses which will reveal certain psychological characteristics in the person who makes them"[5]. The psychological characteristic is not a part of the stimulus-response situation open to objective observation. It is the 'intervening variable' which is used as a hypothetical construct in order to interpret those features of the response that can not be accounted for in terms of the stimulus. The test response is thus treated as a function of the hypothesised psychological characteristic. As the characteristic itself is never open to inspection in sense observation, aided or unaided, its dimensions can never be judged or measured. It is the responses alone that can be quantified. But since the responses are not to be treated in their own right, but as revealing the characteristic, their quantification is accepted as a quantification of the characteristic itself. Hence we never arrive at a direct measurement of a psychological characteristic. All psychological tests, whatever their status in the field of measurement, are indirect measures of the attributes they profess to measure.

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[5] Mursell, J. L. Psychological Testing, Longmans, p. 1.

Psychological test scores do not provide absolute measurements. They are not indicative of a given magnitude of the characteristic measured in terms of any conventionally accepted unit of measurement, as is the case in the physical realm. The unit of measurement is the test item which is never the same either in the same test or in different tests measuring the same psychological characteristic. The number of items too varies from test to test, though all may be measuring the same psychological attribute. The length of a test is decided upon grounds of administrative convenience or for statistical reasons. That is why a test score has no meaning in itself. It comes to have a significance only when related to other test scores that can possibily be made in the same test, that is, as being more or less than other scores. Since the meaning of each test score changes in relation to another made in the same test, a score is sought to be established which depends for its significance on an external source. This is the score made most often by a representative sample of the population to which the test is intended to apply. It lends a point of reference to all other scores made in the test and thus functions as a norm for the test. The significance of psychological test scores, and, therefore, the value of a test, is limited to the population with respect to which its norms have been constructed. This point is very important to remember for all users of psychological tests.

In constructing test norms, it is not possible, nor it is worth while, to use the entire population even of a very restricted area. Norms are to be constructed on a representative sample of the population. Only such norms are expected to remain stable and thus function as fixed points of reference for the interpretation of the scores made in the test. This is another very important matter which is generally overlooked by test constructions in this country. Only tests standardised on a representative sample of a given population can be of any real value.

PSYCHOLOGICAL TESTS AS TOOLS OF DIAGNOSIS

Psychological tests have some advantages as tools of diagnosis which are lacking in other methods. They are extremely handy and can be administered and scored without calling for any special technical skill or talent. Even the clerical staff, with some experience, can be safely trusted to look after the job. They are least time consuming as compared to the method of case history or interview. They are objective and reliable sources of information regarding such psychological characteristics as general ability, interest, special aptitudes and scholastic attainment. Since they express the characteristics measured in quantitative terms, their results can be precisely interpreted. They enable one to make comparison and classification more easily than is possible by any other method. Test profiles offer a very convenient medium for presenting the relative strengths and weaknesses of the client.

Psychological tests are valuable diagnostic instruments for vocational guidance. But the information furnished by psychological tests is sketchy and far from comprehensive. It fails to serve the requirements of conclusive diagnosis. It has been recognised by psychologists that very limited sectors of an individual's personality can lend themselves to quantification. There are many psychological characteristics of no less vocational significance that defy any attempt at measurement. Even the measurement of intelligence which was the earliest to emerge covers a very restricted range of the functions associated with intelligence as 'the all round general ability' that contributes to educational and vocational success. Taken in the very limited sense of a measure of scholastic aptitude, as intelligence tests are generally understood, their use is confined to the assessment of the capacity to comprehend and use verbal and numerical symbols. Leaving aside a multitude of the nonintellective functions that go with academic success, the standard tests of intelligence fall short of providing a reliable index of such qualities of the intellect as assimilation, organisation and creativeness. These influence, in increasing amounts, the onward educational progress of a child. Objective tests of scholastic attainment also fail to supplement the data lacking in an intelligence test programme. They commonly measure the information possessed by an individual, but less often measure the ability to apply information. 'They seldom yield any evidence regarding appreciation and critical discrimination'.

Vocational guidance workers display a special liking for special aptitude tests. Some of them behave as though vocational guidance is synonymous with aptitude testing. But the diagnostic value of the aptitude tests that are generally in use is still more limited than is the case with intelligence tests or scholastic attainment tests. Tests of mechanical aptitude and of clerical aptitude are among the very largely used paper-and-pencil aptitude tests. A mechanical aptitude test gives evidence of a person's extent of knowledge regarding names and uses of tools and parts of machinery. It throws no light upon his ability to use those tools or to comprehend their functions in a complex vocational setting. Same is true of clerical ability tests. They measure accuracy & speed of perception of verbal & numerical symbols which constitute a very limited part of the duties & responsibilities of a competent clerical worker.

Tests of interest and personality are still less comprehensive and confined to very limited and isolated sectors of a person's attitudes & disposition. They are also much less reliable as sources of information. The data furnished by them are based upon the knowledge that a person has about himself and, therefore, are limited by his capacity for self-observation. The responses made to the test items are not only affected by a person's conscious effort to present an acceptable picture of himself, but also by other unwitting factors beyond his control. The need to preserve self-esteem or ego-value colours, more or less, every person's perception of his own assets and liabilities, likes and dislikes, inclinations and aversions. Psychological literature is full of experimental evidence on this point. It has been consistently noted that the influence of need on perception is never so predominant as when the perception involves knowledge of and report about one's own psychological characteristics.

It follows that psychological tests fail to provide, to the guidance worker, complete information about the clients assets and liabilities. Thus even as diagonstic tools they fall short of their professed functions. "As the client and the counsellor come together, the client may realise that the area he is able to measure with his psychometric tools is small and at times relatively unimportant. For that matter the unchartered seas of total adjustment and total behaviour are far vaster than the small and better known islands that constitute the measurable characteristics. To attempt to infer the whole from the meagre measurable sample is an indefensible procedure''.[6]

There is another serious flaw in a vocational guidance programme that predominantly leans upon psychological tests. Vocational guidance must have a personalitistic bias. Its programme must be steered to the needs of the individual client and should aim at assisting him to plan out a vocation for himself that is consistent with his potentialities and attainments, on the one hand, and with the opportunities offered by his environment on the other. But this end can be realised only when the information concerning the facts on which the plan is to rest, is exact and, relatively, free from error. Psychological tests have not reached that level of refinement as to yield exact measurement. ''The measuring instruments that we now use even for the most adequately measured traits such as intelligence and vocational interests are still crude and only half understood, those we use for measuring personality traits such as general adjustment, introversion and the need for recognition are still in embroynic stage''.[7] The information about an individual that a mere testing programme offers is strongly liable to error. Whatever prediction is made on its basis regarding the cliant's prospects of vocational adjustment is as likely to hold for him as not.

Psychological tests are grounded on statistical methods. They provide measures of group trends or tendencies and may possess high predictive value as such. When applied to the individual case, their results may be vitiated by a multitude of extraneous factors playing in chance order. These erroneous factors cancel each other when one transcends the limits of the individual. An extension of the results bearing upon general tendencies of a group to diagnosis and prognosis of an individual case is naturally exposed to grave risks.

Psychological tests have proved their usefulness in industrial selection since the effectiveness of the selection is seldom judged from the side of its value to the individual employee. A particular worker selected on the basis of tests may not turn out to be a success at the job. A testing programme recommends itself on the ground of the total gain to the employer. We cannot afford to present the same attitude with respect to vocational guidance.

Psychological tests suffer from an inherent defect which lowers their diagnostic value considerably. They generally have poor validity which cannot be compensated by their oft-quoted high reliability. The forecasting efficiency of a test is a direct function of its validity. The co-efficient of validity quoted for some of the best tests of intelligence does not exceed 0·7, and that too in very exceptional cases ; the average value ranges between 0·45 and 0·55. Same is true of the vocational aptitude tests. A validity co-efficient of 0·5 can scarcely warrant successful prediction in more than a negligibly small percentage of cases, the corrosponding value of the co-efficient of alienation being 0·866. ''The errors of estimate for r's in the vicinity of ·40 to ·70, values usually found and utilised in predicting success from test results, are discouragingly large''.[8]

The validity of personality measurement, including the projective tests like Rorschach and T.A.T., is still poorer, though personality data are of no less importance, in vocational guidance. Occupational adjustment is not the bare function of appropriate aptitude and interests. Emotional difficulties, temperamental defects and poor personality development handicap an individual in solving his occupational problems on the practical level, despite his uncommon endowments of ability and aptitudes. Many a gifted person has made a mess of his life on account of his personality problems. A guidance worker who overlooks the non-testing methods of persoality diagnosis because of his uncritical devotion to psychological tests is treading on extremely unsafe grounds!

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[6] Sanderson, H. Basic Concepts in Vocational Guidance, p. 163. McGrow Hill Book Co. Inc.

[7] Super, D.E. op. cit., p. 8.

[8] McNemar, Quinn. Psychological Statistics, 2nd edn., p. 137.

Apart from being low or poor, the co-efficient of validity reported for a psychological test may not have a precise meaning. The validity of vocational aptitude tests, more particularly, has significance only in relation to the criterion used for its validation. But the criterion may have no relevance to the guidance programme in which the test is used. An engineering aptitude test, for example, may have been validated against success in the engineering course. But the reported validity co-efficient might delude a guidance worker to utilise the test for predicting success in engineering as a profession. In fact the level of professional competence achieved by an engineer, or for the matter of that by a person attached to any other profession, is not necessarily expected to be consistent with the order of his achievements in the related academic course. Professional competence demands also certain characteristics other than those making for success in the professional training course. Attractive manners, persuasive speech, eagerness to help, and disregard for personal comfort may augur better for the success of a medical graduate in the profession than does an unparalleled record of academic brilliance.

PROSPCT OF TEST-CENTERED VOCATIONAL GUIDANCE IN INDIA

A vocational guidance programme limited to test analysis and interpretation, howsoever extensive, fails to fulfil the real aim of vocational guidance. Tests provide evidence regarding the client's potentialities. They can not make decisions for him. "From careful measurement it may appear that a student's chances of average success in a course in electrical engineering, or in medicine, are one in one hundred. But the tests can not decide for a person whether or not he shall attempt the course or the profession. Often a person must experience failure in order to be made to realise his limitations".[9] The guidance worker may formulate a vocational plan on the basis of an elaborate & comprehensive programme of psychological tests. But the plan may not be consistent with the aspirations of the client. The information concerning his assets & liabilities may not inspire trust and evoke acceptance. The client reserves his right of self-determination and self-direction and may not be willing to renounce it in favour of his counsellor.

The future of a vocational guidance service centering round 'test analysis, fact-finding and occupational information' can be well foreseen in the present set-up of our country. We are committed to establishing a socialistic pattern of society—an economic and social order based upon the values of freedom and democracy. The goals set in our national development programme are influenced by this fundamental concept regarding our national economy. The network of guidance service we aspire to spread in the country in order to prepare for achieving the targets proposed in the

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[9] Greene, E. B. Measurement of Human Behaviour, Rev. Ed., p. 16. The Odyssy Press.

Five-Year Plan, has to be supported and sustained by the same democratic impulse. We can not venture to accept vocational guidance as a process "Whereby counsellors and teachers sort out boys and girls as a grading machine sorts apples—this one to stay on the farm, that one to work in an airplane factory, this one to be a teacher, that one to run the local garage".[10] We can hardly afford to visualise the guidance worker as taking decisions for the client. The ultimate choice has to rest with the client.

A parent desiring his child to join a technical course in the higher secondary schools can hardly be forced against his will to reconcile to an arts course, or a course in agriculture, simply because the vocational guidance expert deems the child fit for the said course. Or, an adult planing his future in business can not be prevented from taking the next step because the guidance personnel of the Youth Employment Service has decreed that he is suitable for a highly lucrative job in the army.

Reduction of unemployment, if not its complete elimination, is one of the principal objectives set forth in the Second Plan. The programme of large scale industrialisation which is the main burden of the plan is primarily directed to this end. Mobilisation of the man-power potential in the country and expansion of training facilities for all categories of skilled workers have been pushed into strong relief. Adequate measures are being taken to ensure a proper integration of the requirement and supply of educated and technically trained personnel. A scheme has been prepared by an ILO expert which "aims at collecting from employers, both in the public & private sectors, information regarding changes in the level of employment, current and prospective demands for labour, shortages of various categories of personnel and the disposition of the labour force in regard to different occupations and industries. The data will be used for various purposes in regard to man-power planing and to gauge the impact of development plans on employment".[1] In order to strike the balance between the fluctuating conditions of demand & supply of personnel, a continual programme of adjustment through the diversion of man-power potential, from time to time, in needed directions is highly essential. A vocational guidance service limiting its responsibility to diagnostic test analysis and occupational information can only partially accomplish this stupendous task.

We can not afford to allow our vocational guidance worker to renounce his responsibility for counselling. His task can never be accomplished with the formulation of a vocational plan. He must realise that his main obligation is to exercise his professional skill as a counsellor and work up a change in the psychological climate of his client. He has to strive for creating such conditions within the client that dispose him, without dispensing with his right of self-determination, to choose and embark upon a vocational plan that is best suited to his ability, aptitude and attainments. Only thus can vocational guidance service be steered to the national drive for reduction of unemployment through large scale industrialisation of the country.

THE TEMPTATION FOR PSYCHOLOGICAL TESTS

I shall be misunderstood if my words are taken to imply a denunciation of psychological tests. Psychological tests are really valuable tools for those who are conscious of their limitations. They are dangerous weapons in the hands of the unwary and the unscrupulous. They hold out a special temptation for the inexpert because of their ease of administration and scoring. They seem to lend to the guidance programme a scientific character for their results are quantitative and their interpretation is 'untainted with the subjectivity and relativity' of the non-testing methods of guidance. They thus cater to the ever unsatiated need of the psychologist for recognition as scientist. Qualified as such, the guidance worker finds himself able to see eye to eye with the physicist or the engineer. He clings to the test programme more & more steadfastly as it brings him a cumulative gain in prestige. The testing service has a special attraction for the novitiate as it provides him a short-cut to scientific status—a test administration and interpretation programme makes little demand for the acquisition of a special skill or development of a particular talent.

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[10] Educational Policies Commission, Education for all American Youth, p. 39, National Educational Association of the United States, Washington, DC.

[11] Expansion of Employment Service Activity, Employment News, Vol. 1. No. 12, Ministry of Labour, Government of India, New Delhi.

A vocational guidance worker stresses the importance of vocational aptitude in occupational adjustment and always looks for an aptitude when required to advise a client. But he seldom cares to search for an aptitude related to his own professional undertaking. Doctors are bad patients. The treatment they prescribe for others drives them into temper tantrum when they are suggested the same for themselves. So is our vocational guidance expert. Or, one might interpret his over-emphasis on aptitude testing as a defence against lack of aptitude in himself. His professional competence does not rest on the development of any aptitude. All that is needed is familiarity with the psychometric tests in vogue, a level of practice in their administration and scoring, a fair acquaintance with the available occupational opportunities and their requirements, and, finally, ease and facility, developing with experience, in matching the personal data with the occupational data. A follow-up study or scientific evaluation of the programme is accepted as a part of the guidance service but his preoccupation with the programme spares the test-oriented guidance worker little opportunity to indulge in this time-consuming activity. The evaluation of the test-centred vocational guidance remains an unaccomplished task. The threat to the prestige of the guidance worker is thus warded off under the veritable excuse of an overload of assignments. The immediate purpose of the guidance service is achieved. A vocational plan is chalked out for the client which rests on the stable foundations of unassailable psychometric evidence and inexorable occupational facts.

Psychometric tools have special appeal for some guidance workers as they provide them at times an easy way out of a highly threatening situation. A person seeking guidance may approach the worker with high hopes in his undisputed power to help him achieve his long cherished vocational goal. The guidance worker may discover that the client's aspirations are far beyond his capacities for achievement and may be called upon to suggest for a renunciation of the goal. The situation is highly menacing both for the counsellor as well as the client. The client has to be warded off against the rude shock as it is likely to induce in him a feeling of frustration and thus lower his self-confidence and loosen his grip over his constructive functions. The counsellor has to protect himself against the displaced aggression likely to be engendered by the feeling of frustration. The situation entails a special demand on the counselling skill of the guidance worker. An inadept counsellor can seldom find himself equal to the task. Psychometric tests offer him an easy way out of the impasse.

Sanderson[12] has very ably illustrated the situation with the case of Paul, a high school graduate with business course. Paul was a man of average ability but had proved failure in a number of odd jobs tried in succession. "Despite the sad work experience Paul does not want to be 'just a labourer'. He would like to work himself up to a respectable position just as 'office manager' or 'liquor salesman for some big concern' ".

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[12] Sanderson, H., op. cit., pp. 152-154

"During the first counselling session the counsellor was at a loss as to what to do". The case history forwarded by the referring agency contra-indicated the prospect of industrial employment or that of sales & clerical work. Learning a trade was ruled out by Paul's negative attitude toward manual occupations. "The counsellor himself was in a quandry but he felt that it was his responsibility to indicate to Paul what vocational plans he should make. Since the counsellor did not know in what areas Paul could be relatively successful, extensive psychometric testing was undertaken. Approximately twelve tests were administered during three consecutive mornings. The tests revealed nothing that had not been already known or could not have been inferred from the case history and the interviews". A comprehensive summary of the psychometric data was mailed to the referring agency, despite the fact that Paul was not helped with his occupational problem.

"Psychometric testing, however, offered a seemingly easier way out of the dilemma. It provided the counsellor with the impression that he was discharging his professional obligations, it offered the referring agency an opportunity to ponder over the quantitative data. Every one seemed to be satisfied except Paul".

The client's unsalutary reaction to the testing programme is another drawback of test-centred vocational guidance. Tests "tend to increase defensiveness on the part of the client, to lessen his acceptance of self, to decrease his sense of responsibility, to create an attitude of dependence upon the expert".[13] If the test findings are in opposition to his cherished ideals, the client either disregards the test results and holds on to his vocational plan more stubbornly, or, puts undue premium on the test findings and uses them as a face-saving device against his failure to accomplish his goal. It is only counselling that can come to his real rescue by lending him insight and strengthening his faith in those potentialities and assets that he had so far disregarded because they were out of harmony with his professed occupational goal. By working out a change in his system of values, counselling provides the conditions for the emergence of an occupational plan that is consistent with the client's ability, aptitudes & temperament.

PSYCHOLOGICAL TESTS NOT INDISPENSABLE FOR VOCATIONAL GUIDANCE

I may be permitted to go even to the length of remarking that psychological tests are not indispensible tools in the service of effective vocational guidance. Their usefulness is restricted to a diagnosis of the client's potentialities and this too in a limited sense. A vocational guidance worker has to look for the non-testing services as well in order that he obtain comprehensive data about the client and arrive at a conclusive diagnosis. Even the limited information furinshed by psychological tests can be obtained by the non-testing methods as well. "Tests will rarely, if ever, reveal anything about a client that a competent counsellor can not ascertain without their use".[14] Only, "when a suitable test is available, its use will generally save time and obtain the information in a more objective, valid and usable form than would otherwise be the case".[15]

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[13] Rogers, C. R., Psychometric Tests and Client Centred Counselling, Educ., Psychol., Measmt., 1946, 6, p. 141.

[14] Sanderson, H., op. cit., p. 162.

Psychological tests do not find favour with Russian Psychologists.[16] Nevertheless, now that the iron-curtain is withdrawn, one can not help appreciating the monumental success Soviet Russia has achieved in pushing forward her schemes of national development. The training and placement programmes of her technical men-power could never have gained the great strides without 'the right man for the right job'. I am referring to the attitude shown by Russian psychologists to tests just to impress upon you that psychological testing can not be accepted as the sine quo non of effective vocational guidance. Tests are valuable instruments, but only when their significance and validity are well ascertained and, what is no less important, their limitations are fully recognised. In the absence of this, a non-testing programme systematically planned and carefully worked is to be generally preferred.

CONCLUSION

Before I conclude, I would like to reiterate that my purpose has not been to run down psychological tests. In fact, as it is known to many of my colleagues, I can claim to have made a little bit of contribution to the growth of psychological testing in this country. I only feel it imperative, at the moment, to draw your attention to the great danger that is lurking in the exaggerated stress that is being laid on mental tests, knowingly or unknowingly, by guidance workers in this country. Counselling, which is the core of the guidance service, is being denied its due place. Vocational guidance courses are being planned at different centres ranging in duration from four to eight weeks. Such short courses may supply the minimum essentials of the supporting services in vocational guidance which aim at the collection and systematisation of pertinent personal and occupational data. But they can not touch even the preliminaries of the discipline that qualifies a guidance worker for the major responsibilities of counselling. It is his competency as a counsellor which is the real test of a guidance worker. This presupposes a thorough knowledge and understanding of the facts and principles of psychological dynamics—not only at the theoretical but also at the functional level, development of an impersonal objective attitude of the scientist but devoid of cold-bloodedness, and, finally, the acquisition of an uncommon skill in interviewing.

It is a great pity, as I have already mentioned, that vocational guidance experts fight shy of putting vocational guidance on the same level with other vocations and disregard the significance of individual differences in this area. Any person satisfying a minimum standard of academic qualifications, generally Master's degree in Psychology or Education, is liberally admitted for training in vocational guidance. Aptitude, interest. personality traits, so much talked about when considering the prospect of success in any other vocation, are regrettably ignored when preparing a person for the job of guidance worker.

It is necessary that we draw a line between the two levels of training : (1) that for supporting services in vocational guidance and (2) that for the major responsibility of guidance, namely, counselling. A short course. covering six to eight weeks, may be deemed as the necessary minimum for the former. But even for this course, the admission should not be indiscriminate. Some evidence of aptitude for developing proficiency in the work should from the basis, besides a certain standard of academic attainment. The selection for the second course should be more rigorous. A well thought out and planned programme has to be worked out for this purpose. The duration of the course should cover not less than one, if not two, academic years. Due stress should be given to the practical, actual-life-situation, side of the training. Since it is not my purpose here to deal with the subject of training, I would leave it for an appropriate treatment on some other occasion. My aim is only to emphasise that a test-centred vocational guidance service faces the risk of confusing the smoke for the fire. Every guidance worker needs to remember that the secret of occupational adjustment, which is the avowed aim of all vocational guidance programmes, does not lie in the knowledge that a person, or for the matter of that, his counsellor may obtain regarding his (client) potentialities but in his capacity to make optimal use of his potentialities. This is beyond the reach of a test-centred guidance service.

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[15] Super, D.E., op. cit., p. 8.

[16] Wortis, J., Soviet Psychiatry, Baltimore, Williams Welkins.

SECTION OF ENGINEERING AND METALLURGY

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CONTENTS

I. Introduction ... ...
II. Structure of atoms ... ...
III. Atoms in crystals of metals and alloys—the Brillouin zones and their implications ... ...
VI. Fundamentals of extraction of metals ... ...
V. Ionic theory of slag ... ...
VI. Ionic nature of molten alloys ... ...
VII. Development of new alloys—establishment of Alloy-Steel and Ferro-Alloy plant ... ...
VIII. Surface phenomena and diffusion ... ...
IX. Imperfections in crystals—dislocations ... ...
X. Stress and strain in metals and alloys ... ...
XI. Nuclear Metallurgy ... ...
XII. Fundamentals of Metallurgical and Engineering education ... ...
XIII. Concluding remarks ... ...

I. Introduction

I extend my sincere thanks to you all for having elected me to the office of the President of the Engineering and Metallurgy section of the Indian Science Congress Association. As one who has humbly toiled in the field of education and research for more than twenty five years I shall lay before you some aspects of metallurgical research and education with particular reference to those that may be helpful for an overall growth of fundamental and industrial research in this country in the field of metals and alloys and also development of advanced metallurgical education which is so essential to initiate and sustain research.

Metallurgical engineering as an art is one of the oldest of engineering professions but metallurgy as a science is one of the newest and inspite of the large volume of work (in many cases of great precision and of fundamental value) there is nevertheless a large area which offers opportunities for both fundamental and applied metallurgical research. It is not possible to discuss or even glance briefly over all the area within the limited scope of this address. I shall endeavour therefore to present some of the important aspects of a few fields which I had the opportunity to work on and a few others which I had the opportunity to survey.

Metallurgy or metallurgical engineering is often divided rather artificially, into two branches—the Ferrous & the non-Ferrous. Having worked for more than seventeen years with M/s. The Tata Iron & Steel Co. Ltd., I must confess that my mental frame work is essentially "Ferrous". I may be pardoned therefore, if in discussing metallurgical research, I have drawn upon materials in the field of iron and steel and made references often to ferrous research. I may point out however that the fundamental laws governing metallurgical reactions and phenomena in the field of iron and steel are applicable equally well in the field of non-ferrous metals. Metallurgical science as it stands today can hardly draw any line of demarcation between ferrous and non-ferrous metallurgical research and education. Details of specified fields of study may vary but the fundamentals remain the same.

Almost all metals and alloys are polycrystalline, that is, consist of a large number of small grains oriented at random and surrounded by grain boundaries. Each of these small grains of different shapes and sizes are made up of extremely tiny crystal blocks which are again made up of atoms and ions arranged in certain definite patterns called "crystal lattices". The behaviour of a piece of metal or alloy depends essentially on

(*i*) The nature of the grains and grain boundaries.
(*ii*) The nature of the crystal lattices (and lattice imperfections).
(*iii*) The nature of the atoms and/or ions making up the crystal lattices.

Many of the engineering properties of metals and alloys may be explained on the basis of factor (*i*) above viz, nature of the grains and grain boundaries with particular reference to the different phases—their shapes, sizes and modes of distribution ; but the fundamental reasons for almost all properties of metals and alloys are untimely to be sought in the factors (*ii*) and (*iii*) above viz. the nature of the crystal lattices and lattice imperfections and the nature of the atoms and ions which make up these lattices. *The foundation of metallurgical education and research,* I have no hesitation to feel, *should be planned and based on a fuller understanding of a few basic fundamentals which involve some details of the answers to the following few questions.*

I. What are atoms and ions?
II. (a) How do these atoms or ions, particularly the valence electrons and/or electrons in the outer orbitals behave, when they form a solid lattice?
  (b) How does the solid lattice behave when subjected to external stress and/or electrical or magnetic field?
III. What happens when this solid lattice is exposed to a certain environment and reactions start at the surface and/or interface and gradually spread throughout its volume by the process of diffusion?
IV. What modifications are to be introduced due to lattice imperfection and grain boundaries in polycrystalline metals and alloys?
V. (a) How are statistical mechanics and thermodynamics (of reversible and irreversible processes) helpful in understanding the behaviour of the group?
  (b) What are the effects of temperature and time (Kinetics) and other physical environments on metallurgical reactions?
VI. (a) What are the effects of high energy particles (waves) and/or radiations of different frequencies on metals and alloys?

(b) Where and how do non-Newtonian mechanics (relativistic and/or quantum) play vital parts in our understanding of some of the frontiers of knowledge in different fields of engineering and technology and in appreciating the limitations of our theoretical knowledge on the one hand and practical endeavours on the other?

I must humbly confess that I do not propose to answer all these questions in this address. Many of these questions, as some of you are already aware of, have yet to be answered fully. Answers to questions I and II (a), (b) are the most important and yet the most neglected. Atoms are the most talked-about but the most ill-understood and therefore the most well-avoided in many attempts to understand and explain the fundamental reasons for the behaviour of metals and alloys. With the clear understanding of the nature of atoms is tied up our understanding of the nature of metallic lattices which build up with some modifications (lattice imperfections and grain boundaries) the metals and alloys we want to study.

II. STRUCTURE OF ATOMS

Of the hundred and odd elements known to man today more than seventy are metals. Metals, like all other matter in the universe, consists of atoms and/or ions. An isolated atom consists of an extremely tiny ($\sim 10^{-13}$cm), dense ($\sim 10^{15}$ gms/cm^3) and positively charged nucleus surrounded by a cloud of negatively charged electrons, revolving round the nucleus in different orbits or "energy states" defined by four quantum numbers n, l, m_l and m_s (much like the position of a particle in a four dimensional space may be specified by four co-ordinates or numbers like x, y, z and t.).

While the nucleus is very important in many fields of study like nuclear reactions, isotope separation, transmutation and particularly development of nuclear power, it does not come into the picture in most of the physical, chemical or metallurgical reactions. It is the outer garb of the atom viz its extranuclear electronic structure that is responsible for its different behaviour under different environments. Before proceeding to understand the extranuclear structure on which a very large number of properties and behaviours of metals and alloys depend, it is necessary to remember that the electron is not only a negatively charged particle, but has definite wave properties. The wave length λ of the electron and also of any material particle, in general, is given by $\lambda = \dfrac{h}{mv}$ . . (1)

where, h = planck's constant.
m = mass of electron.
v = velocity of electron.

This wave nature of the electron is a physical reality and is extremely important in understanding the nature of the behaviour of metals and alloys. Electron microscopy and diffraction (which have in recent years been a powerful tool to extend the frontiers of metallurgical knowledge) is based on the wave properties of electrons. Along any arbitrary direction x it is obvious that the displacement Ψ of a vibrating medium may be represented by the simple wave equation,

$$\Psi = \text{Sin}\,\frac{2\pi}{\lambda}x \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

and thus the differential equation may be found and expressed as

$$\frac{d^2\Psi}{dx^2}+\left(\frac{4\pi^2}{\lambda^2}\right)\Psi=0 \quad . \quad . \quad . \quad . \qquad (3)$$

If in a system the total energy of the electron be E and its potential energy be V, the kinetic energy (non-relativistic) is given by,

$$\tfrac{1}{2}mv^2=E-V \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

combining (1) and (4) one gets

$$\frac{1}{\lambda^2}=\frac{2m(E-V)}{h^2} \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

Equation (3) may therefore be written as

$$\frac{d^2\Psi}{dx^2}+\left[\frac{8\pi^2m}{h^2}\,(E-V)\right]\Psi=0 \quad . \quad . \qquad (6)$$

Equation (6) may be recognised as the one-dimensional schrodinger wave equation. In three dimensions one may write

$$\nabla^2\Psi+\frac{8\pi^2m}{h^2}\,(E-V)\Psi=0 \quad . \quad . \quad . \qquad (7)$$

It is well known that in the theory of physical optics (or in any vibratory process in general) the intensity of light or the probability of finding a photon (light quantum) at a given point is proportional to the square of the amplitude. In the case of the electron, similarly, the square of the amplitude of vibration (or in general $\Psi\overline{\Psi}$ where $\overline{\Psi}$ is the complex conjugate of Ψ) is a measure of the probability of finding an electron.

Like other differential equations, equation (6) in general has an infinite number of solutions. For all actual problems of an electron moving in a certain potential field however (as in the case of a simple atom) *only certain real discrete solutions of* (6) can be physically acceptable. The interesting part of the problem with stationary states of electrons in atoms or crystals is that the *acceptable solutions involve whole numbers which are known as* "quantum numbers".

The first or the principal quantum number n is a measure of the energy of the electron and determines approximately its average distance from the nucleus. The second quantum number l is a measure of of the angular momentum of the electron due to its revolution round the nucleus and for a given value of n, l may have any value between 0, 1, 2 . . . . (n−1). Being a charged entity, the revolution of an electron involves a magnetic moment. The third quantum number m_l is a measure of this magnetic moment. For a given value of n and l, m_l may have any value between −l to +l including zero. Apart from its motion round the nucleus, the electron spins on its own axis and this gives rise to the spin quantum number m_s having values $\pm\frac{1}{2}$ (signifying opposite spins). The letters K, L, M, N—are used to represent the shells for n=1, 2, 3, 4 . . . . and the letters s, p, d, f, ... to represent the sub-shells for l=0, 1, 2 3 . . . .

The inert gas structures corresponding to those of He, Ne, A etc. are of great significance to the metallurgists because like many chemical reactions, metallurgical reactions are often caused by changes in the electron structures of atoms leading to inert gas stable structures. Moreover many so-called anomalous behaviour of slag metal reactions may be explained on *this basis. It is sometimes found for example that the activities of some of the ions in molten slags and metals in some important metallurgical processes like dephosphorisation or desulphurisation of steel are not very much affected by other atoms or ions. This may well be explained on the basis of the inert gas structures of the ions concerned.*

III. ATOMS IN CRYSTALS OF METALS AND ALLOYS—

THE BRILLOUIN ZONES AND THEIR IMPLICATION[1, 2, 79]

When atoms approach each other to form a lattice, the electrons in the inner orbits remain more or less unaffected but the motion of the electrons in the outer orbits are altered in such a way that the Ψ-patterns of individual atoms fit in continuously with that of its neighbours. This leads to a gradual broadening of the energy levels of the outer orbits which may overlap and the electrons are then said to occupy hybridized orbitals and are described by the super-position of two wave functions (corresponding to the overlapping orbits). If one imagines a block of metal of volume V (containing n′ valence electrons) then from Pauling's Exclusion principle there will be $\frac{n'}{2}$ or N occupied states with two electrons of opposite spins in each state. From Heisenberg's Uncertainty principle, it may be shown that in the momentum p-space (Fermispace) [1, 2]

$$N=\frac{4}{3}\pi V\left(\frac{2m}{h^2}E\right)^{\frac{3}{2}} \quad . \quad . \quad . \quad . \qquad (8)$$

If $\frac{dN}{dE}$, the number of states per small energy range be represented by N(E) one gets

$$N\ (E)=\frac{dN}{dE}=2\pi V\left(\frac{2m}{h^2}\right)^{\frac{3}{2}} E^{\frac{1}{2}} \quad . \quad . \quad . \qquad (9a)$$

or,

$$\frac{N(E)}{V}=2\pi\left(\frac{2m}{h^2}\right)^{\frac{3}{2}} E^{\frac{1}{2}} \quad .. \quad . \quad . \qquad (9b)$$

Thus for given volume, N(E) as function of E is a parabolic curve as shown in the dotted plot oag of Fig. 1 (a).

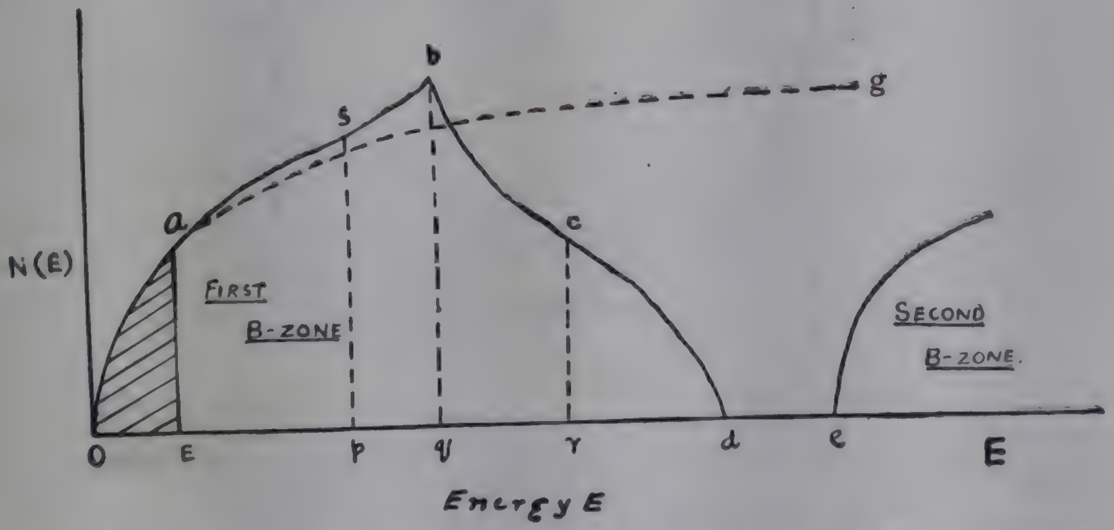


FIG. 1(a). Oag is the classical parabolic N(E) curve for free electrons corresponding to equation 9(a). The full line plot oabcd represents the N(E) curve for the electrons in the cubic lattice for which the first two-dimensional Brillouin-Zone is the square ABCD shown in Fig. 1(b).

Since the constant of proportionality in equation (9b) contains only m (and the universal constant h) which, in a nonrelativistic treatment remains constant, it would appear that N(E) curves for all metals and alloys would follow the same pattern. That this is not true follows from two important considerations viz.

(*a*) that electrons have a wave pattern.

(*b*) that electron waves like x-rays suffer diffraction during their motion within the crystal lattice according to the well known Bragg's law.

$$2d \sin \Theta = n_1 \lambda \quad . \quad . \quad . \quad . \quad (10)$$

where d is the interplanar spacings and Θ is the angle of incidence of the electrons on crystal planes. In the periodic field characteristic of the structure of the metal or alloy concerned (FCC, BCC, HCP etc.) one imagines a k-space (much like the momentum or p-space) defined by

$$k = \frac{1}{\lambda} = \frac{h}{p} \quad . \quad . \quad . \quad . \quad . \quad (11a)$$

or,

$$E = \tfrac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{h^2}{2m}k^2 \quad . \quad . \quad . \quad (11b)$$

Sometimes for mathematical convenience [see wave equations (2) and (3)] k is represented by $\frac{2\pi}{\lambda}$. In the k-space increasing radius vector from a given origin implies increased value of k and hence decreased value of λ, that is, increased value of energy. As electrons are added in the crystals they continue to occupy higher energy states (each with opposite spins)

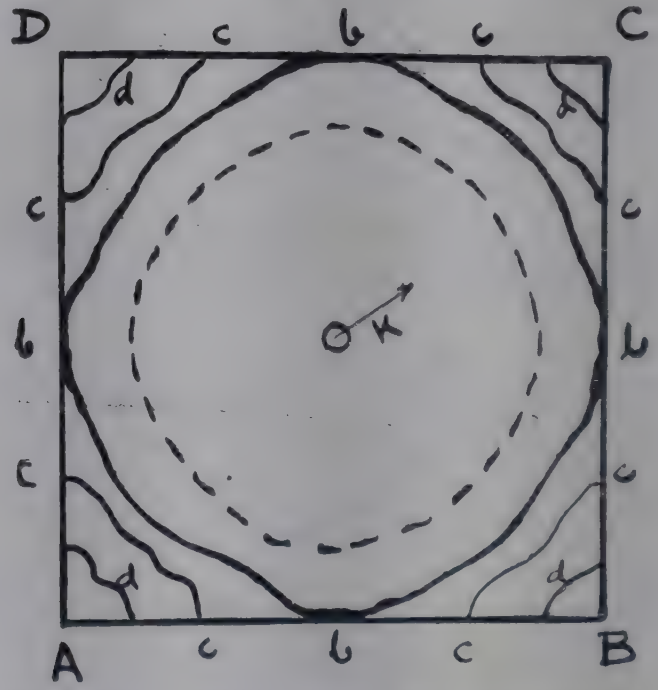


FIG. 1(b). ABCD is the two dimensional first Brillouin zone for a cubic lattice corresponding to the full line plot oabcd of Fig. 1(a). The Fermi-sphere in the k-space is represented by the dotted circle. With increasing energy of the electrons the sphere gets distorted as indicated by the contour bbbb. Other contours like cc, dd, etc. represent states of increasing energy of the electrons in the first Brillouin Zone.

and fiill up an increasing sphere in the k-space (like the Fermi sphere of free electrons in a momentum space) till a critical λ, that is, a critical k_c is reached which satisfies the Bragg condition in that particular direction with respect to a certain set of planes within the crystal. At this stage strong reflection occurs and no electrons with motion in this direction can have energies greater than $h^2k^2_c/2m$ (see equation 11b), unless they have sufficient energy to overcome the barrier of energy. For each direction therefore there are a series of critical points k in the k-space where there are discontinuties in electron energy. The locii of these k points for the first reflection along different directious in the k-space form a zone (bounded by surfaces) called the first *Brillouin zone or B-zone*. The first four zones of a simple cubic lattice are shown in Figs. 2 (a), (b), (c) and (d). The shape and size of the B-zones depend only on the shape and size of the unit cell of the metal or alloy concerned and not on the number of atoms. (Fig. 1b).

It is worthy to note however that the shape and size of the B-zone is in the k-space. The shape and size of the B-zone for a given lattice type may be determined from the following considerations :—

(*i*) for a simple cubic lattice it is well known that the miller indices (h,k,l) are given by $h^2+k^2+1^2=1, 2, 3, 4 \ldots\ldots$

The first, second, third and fourth B-zones correspond to diffraction of electrons incident normally ($\theta=90°$) on planes having the miller indices (hkl) such that $h^2+k^2+1^2=1, 2, 3,$ and 4 respectively.

$$\text{Since} \quad d=\frac{a}{(h^2+k^2+1^2)^{\frac{1}{2}}}$$

$$\lambda=2d \operatorname{Sin} 90=2d=\frac{2a}{(h^2+k^2+1^2)^{\frac{1}{2}}}$$

$$\text{therefore,} \quad k=\frac{1}{\lambda}=\frac{(h^2+k^2+1^2)^{\frac{1}{2}}}{2a} \quad \ldots\ldots\ldots\ldots \quad (12)$$

Tnus for the first B-zone corresponding to $h^2+k^2+1^2=1$

$$k_1=\frac{1}{2a}$$

m, the multiplicity factor (that is all possible values of orientation of plane hkl) for (100) plane=6.

Thus the first B-zone for a cubic lattice of parameter a is a 6-sided figure all at distances of $\frac{1}{2a}$ from the centre of k-space. It is therefore itself a cube of side $^1/_a$ in the k-space (Fig. 2a).

The volume of the first B-zone of a simple cubic lattice is equal to $\frac{1}{a^3}$

Similarly for the second B-zone of a cubic lattice

$$h^2+k^2+1^2=2,\ (hkl)=(110),\ k_2=\frac{1}{a\sqrt{2}} \text{ and m for } (110)=12$$

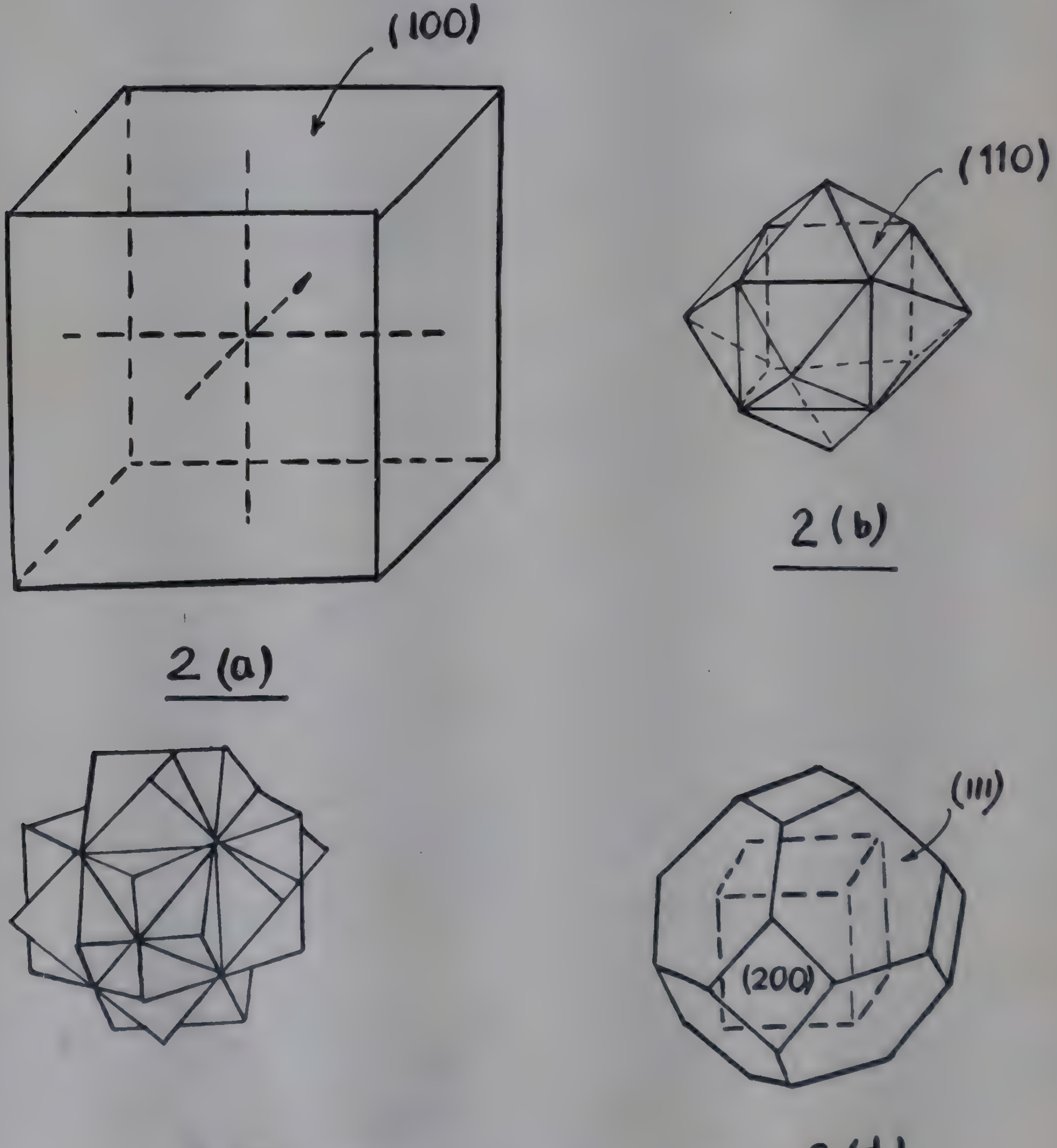
Thus the second B-zone of a cubic lattice is a 12-sided figure (dodecahedron) all at a distance of $^1/a\sqrt{2}$ from the centre of k-space faces and inclined at 45° to the bases (the six faces of the B-zone cube).

therefore, volume of the second B-zone of the cubic lattice

$$=\frac{1}{a^3}+6\left(\frac{1}{3}\cdot\frac{1}{a^2}\cdot\frac{1}{2a}\right)=\frac{2}{a^3}.$$

(*ii*) For a bodycentered cubic (BCC) lattice $h^2+k^2+l^2=2, 4, 6, 8$ etc. Thus for the first zone, $h^2+k^2+l^2=2$, and hkl=(110). This corresponds exactly to the second B-zone for a simple cubic lattice (as discussed above). Thus the first B-zone of a BCC lattice has a similar shape (viz. rhombic dedecahedron, fig. 2b) to that of the second B-zone of a simple cubic lattice—the size depending on the lattice parameter of the unit cell (viz. faces all at a distance of $^1/a\sqrt{2}$ from the entre of the k-space.)

The volume of the first B-zone for a BCC lattice $=\frac{2}{a^3}$



2 (a)

2 (b)

2 (c)

2 (d)

FIG. 2(a), (b), (c), (d). The first four Brillouin Zones for a simple cubic lattice. Fig. 2(b) and 2(d) correspond to the first Brillouin Zone of the BCC and FCC lattice respectively.

(*iii*) For a face-centre cubic (FCC), $h^2+k^2+l^2=3, 4, 8, 11 \ldots\ldots$ Therefore for the first B-zone, $h^2+k^2+l^2=3$, and $hkl=(111)$

Therefore $k=\frac{\sqrt{3}}{2a}$, m for $(111)=8$

The eight faces (all at distances of $\sqrt{3}/2a$ from the centre of the k-space) drawn parallel to (111) plane are shown in Fig. 2d. Obviously these alone do not completely enclose and make up a closed figure in a k-space. One therefore considers also $h^2+k^2+l^2=4$ and $(hkl)=(200)$ and obtains

$d=\frac{a}{2}$ and $k=\frac{1}{a}$, $m=6$

Thus the six faces parallel to (200) plane (each at a distance of $\frac{1}{a}$ from the centre of k-space) are shown in Fig. (2d). These six (200) faces and the eight (111) faces make up the first B-zone of the FCC lattice whose volume may be shown to be equal to $4/a^3$

Just as it is important to know the number of atoms or valence electrons/unit cell of a crystal, it is important to know the number of elctrons/atom or the "electron concentration" ε in a B-zone. This may be obtained in general for the cubic lattice from the following relation

$$\varepsilon=\frac{2a^3}{n}V_B \quad \ldots\ldots\ldots \quad (13)$$

If V_B be assumed to be a sphere in the k-space of radius r_k corresponding to the peak b (fig. 1a) of the N (E) plots of the alloy

$$\varepsilon=\frac{2a^3}{n}\times\frac{4}{3}\pi r_k{}^3=\frac{8\pi}{3n}a^3 r_k{}^3 \quad \ldots\ldots \quad (14)$$

From (12) one gts $r_k=k=\frac{(h^2+k^2+l^2)^{\frac{1}{2}}}{2a}$

$$\text{Therefore, } \varepsilon=\frac{\pi}{3n}(h^2+k^2+l^2)^{\frac{3}{2}} \quad \ldots\ldots\ldots \quad (15)$$

Equation (15) is very helpful to compute the electron concentration ε for any cubic lattice for which n, the number of atoms/cell and the miller indices (hkl) of planes diffracting the electrons are known. For example (i) for BCC lattice, n=2 atom/cell.
Therefore for the first B-zone, for which $h^2+k^2+l^2=2$, one gets from (15), $\varepsilon_1=\frac{\pi}{3\times2}\cdot2^{3/2}=\frac{\pi\sqrt{2}}{3}=1{\cdot}48$ electron/atom. Similarly for the second B-zone, for which $h^2+k^2+l^2=4$

$$\varepsilon_2=\frac{\pi}{3\times2}\,4^{\frac{3}{2}}=\frac{4\pi}{3}=4{\cdot}20 \text{ electrons/atoms}$$

and for the third zone one gets

$$\varepsilon_3=\frac{\pi}{3\times2}\,6^{\frac{3}{2}}=\pi\sqrt{6}=7{\cdot}7 \text{ electrons/atom}$$

The peaks D, E and F of Fig. 3 may be referred to in connection with ε_1, ε_2, ε_3, of the B-zone of BCC lattice.

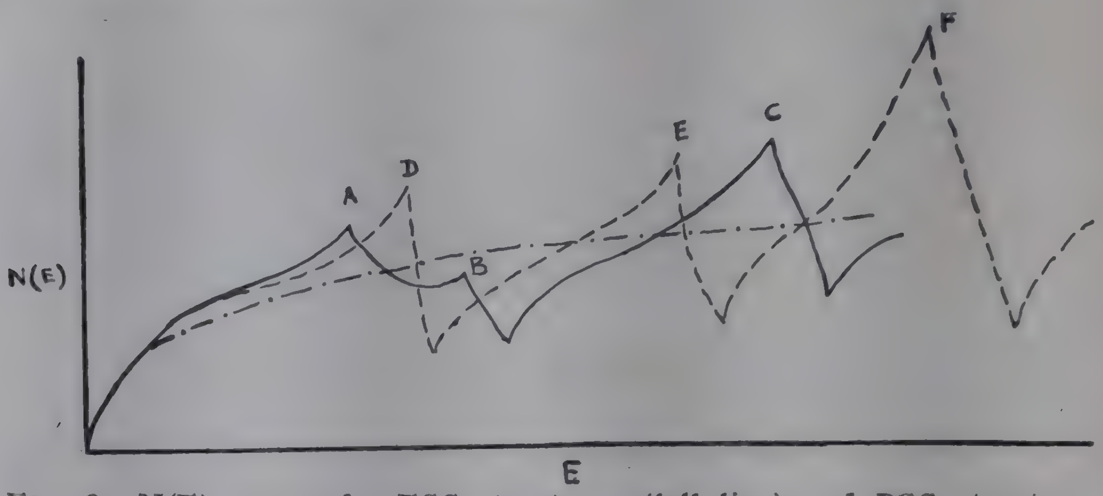


FIG. 3. N(E) curves for FCC structures (full line) and BCC structures (dotted line). The peaks A, B and C correspond to the k-values of the spheres which touch the faces of the Brillouin Zones of the FCC lattice and thus correspond to values of 1·36, 2·10 and 5·9 electrons/atom respectively. The peaks D, E, F similarly correspond to 1·48, 4·21 and 7·7 electrons/atom in the Brillouin Zones of the BCC lattice (after Mott and Jones).

It should be carefully noted that ε_1 refers to the electrons to atom ratio corresponding to the peak in the N (E) curve of the first B-zone. The ε value for the entire first B-zone of the BCC lattice, has a different value which may be obtained from (13).

Since the volume V_B of the first zone$=\frac{2}{a^3}$

$$\varepsilon=\frac{2a^3}{2}\cdot\left(\frac{2}{a^3}\right)=2 \text{ electron/atom.}$$

(*ii*) For the FCC lattice n=4 atom/cell.

It has been indicated before that the first B-zone of a FCC lattice has two sets of faces corresponding to the (111) and (200) of the crystal. Therefore, $h^2+k^2+l^2=3$ and 4 respectively.

Thus from (15) one gets

$$\varepsilon_1=\frac{\pi}{3\times 4}\cdot 3^{\frac{3}{2}}=\frac{\pi\sqrt{3}}{4}=1{\cdot}36 \text{ electrons/atom}$$

Similarly, ε_2 and ε_3 are $\frac{2\pi}{3}$ and $\frac{4\sqrt{2}}{3}\pi$ or 2·10 and 5·90 electrons/atom respectively.

Peaks A, B and C of Fig. 3 may be referred to in connection with ε_1 ε_2, and ε_3 values of the FCC lattice. The ε value of the complete first B-zone of the FCC lattice as a whole is given by (13), viz.

$$\varepsilon=\frac{2a^3}{4}\cdot\frac{4}{a^3}= 2 \text{ electrons/atom.}$$

This value is the same as that of the first B-zone for the BCC lattice.

Equation (15) shows that ε, the "electron concentration" or the number of electron/atom in a B-zone depends on n, the number of atoms/unit cell of the alloy (that is on the nature of its unit lattice, FCC or BCC etc.), and on the values of the miller indices (hkl) of the planes which diffract the electrons at normal incidence.

Thus , the "electron concentration" values in a B-zone of an alloy is independent of the valence, the lattice structure of the solvent and solute atoms and also of the lattice parameter of the unit cell.

While space does not permit discussing further details it may be pointed that the Brillouin zone (B-zone) theory has far reaching implications in explaining some of the fundamental reasons underlying many phenomena in metals and alloys with particular reference to

(A) the theory of alloys.
(B) the electrical conductivities.
and (C) the magnetic properties of metals and alloys.

IV. Fundamentals of extraction of metals[3-21]

Almost all metals (except a few like Au, Pt etc) occur as minerals which are complex mixtures of compounds of metals or metallic radicals (the electropositive part) and nonmentals or nonmetallic radicals (the electronegative part).

The processes of extraction and refining of metals and alloys involve primarily a combination of "Reduction" and "Oxidation" processes which fundamentally involve interactions between electrons in the upper orbitals of atoms governing the different types of bonds and the so-called "activities" of atoms under different environments. Metals in the first and second group of the periodic table with electrons in the s-orbitals (following an inert gas core) are highly reactive and have comparatively lower melting points (except Be). They are therefore usually extracted by electrolysis and not by the conventional pyrometallurgical reduction by C, CO or H_2. The elements in the third group, viz, A1 ($3p^1$ electron) and others (nd^1 electron) are also highly reactive. It is well known that A1 is extracted electrolytically and not by C- reduction. Due to their high reactivities with O_2 (high free energy of formation of their oxides) some of the common and less costly metals in these groups (like Na, A1, Mg, Ca etc) are used as reducing agents for the extraction of other comparatively less reactive but more costly metals (e.g. reduction of Be, Ti or U by Mg, reduction of Cr, Mo by Al, reduction of U and V by Ca and so on). The transition elements with electrons in the 3d orbitals are characterised by high melting points and comparatively less reactivity with O_2 with progressive filling up of their d-orbitals (e.g. Ru, Rh, Pd and Os, Ir and Pt are among the noble metals). After the nd^{10} orbitals are completely filled up the melting and boiling points of the subsequent elements Cu, Ag, Au and Zn, Cd, Hg (with electrons in the ns^1 and ns^2 orbitals) are again low (Zn, Cd, and Hg for example are extracted by reduction and voltalisation methods). Unlike the alkalies and alkaline earths, these elements are not as reactive due to the comparative stability of the higher ns orbitals around the nd^{10} subshells. The subsequent metals Ga (4p) In, Sn, ($5p^1$, $5p^2$) and Tl, Pb, Bi ($6p^1$, $6p^2$, $6p^3$) with electrons in the np orbitals have also comparatively lower melting points and are easily reducible. *The present age however is characterised by the demand of the more "reactive" metals due to essentially two major activities, viz* (1) *flight through space (with or without air and at widely different temperatures) demanding the light metals Al, Ti, Mg and and their alloys* and (2) *development of nuclear energy which has imposed an entirely different types of specifications as regards purity and properties of many metals of which a few essential metals are U, Th, Zr and Be. It is indeed fortunate that nature has been quite generous to this country to supply the raw materials of most of these* *metals (Al, Ti and Mg on the one hand and Th, Zr and Be on the other) and thus to provide the basis for metallurgical and engineering activities and research in both these fields.*

The theoretical possibility of a desired reaction is primarily governed by a few well known thermalynamical laws dealing essentialy with thermodynamic coordinates like P, V, T, G, H, S and activity considerations. The ultimate success and eventually the economics of a process, however, depends on the "kinetics" which in addition deals with the "time" coordinate and considerations on rates of reactions. Reaction rates depend essentially on the frequency of successful contacts between the desired atomic or ionic species and/or other particles. The number of particles η reacting per second is given by

$$\eta = \beta \eta_0 e^{-Q/RT} \quad . \quad . \quad . \quad . \qquad (16)$$

where η_0 = number of collisions/second between reactive particles.
β = the steric factor indicating the fraction of collisions that are favourably oriented $\cong$ 1·0 to 0·1.
$e-Q/RT$ = the probability factor indicating the fraction of collisions which have impact energies greater than the activation energy Q at temperature T°K.

In liquids the value of η_0 is about the same as that in the gaseous phase (about 10^{26} to $10^{30}/\text{cm}^2-\text{sec}$) due to the oscillatory nature of collisions (in contrast to single impacts in the gaseous state) compensating for the loss due to decreased thermal motion. In solids however η_0 is very much smaller and diffusion of atoms becomes the rate determining factor. The steric factor β for simpler particles may be neglected. But the proba-

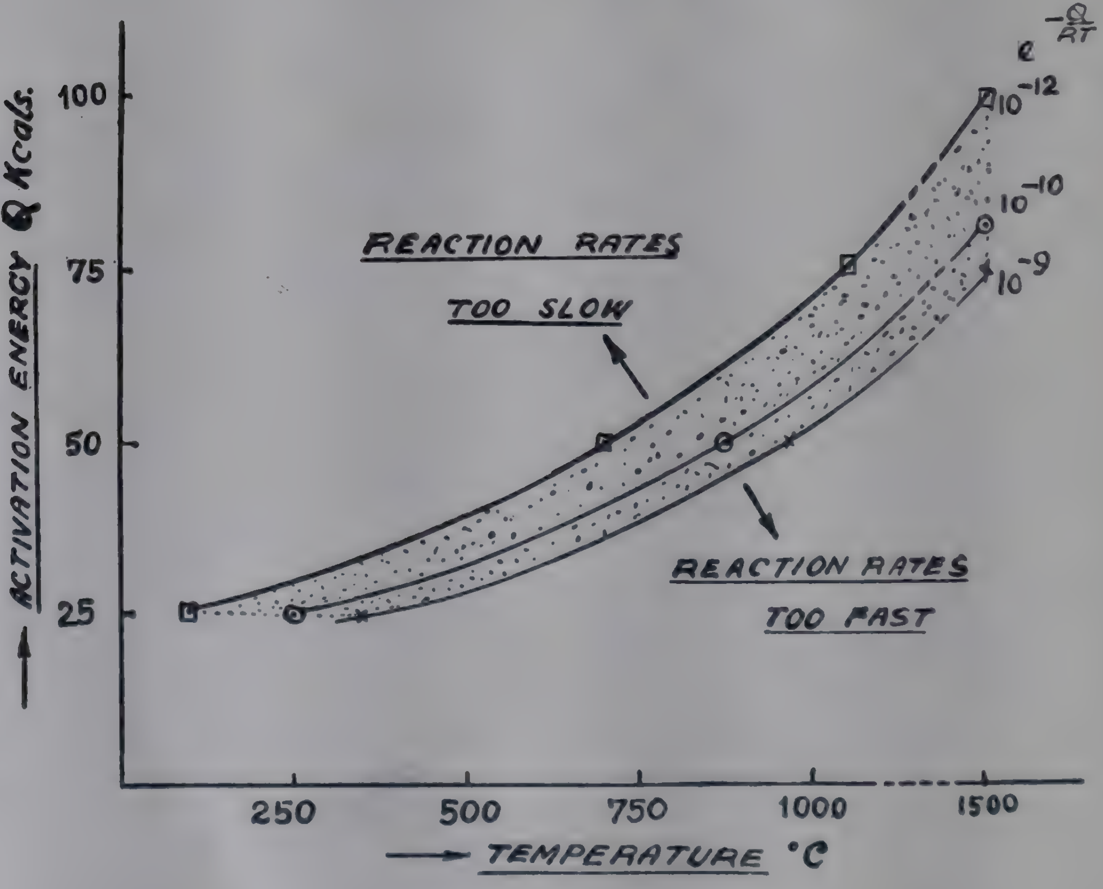


FIG. 4. Different probability factor $\varepsilon^{-Q/RT}$ in relation to the activation energy Q as function of temperature T for almost all metallurgical reactions.

bility factor which depends on Q and T is very important. For most of the metallurgical reactions the activation energy varies between 25 to 75 K- calories. The reaction rates are usually too fast or too slow to measure, if the values of $e^{-Q/RT}$, the probability factor, are greater than 10^{-9} or smaller than 10^{-12}. Figure 4 indicates the effects of the probability factor as function of Q and T. From this plot an estimate may be made of the activation energy from the temperature at which reaction begins.

All factors (the ratio of surface to bulk, diffusion of atoms etc) which increase η_0 increase also reaction rates. The effects of increasing slag-metal contact area and decreasing the depth of bath increases η_0. Similarly diffusion plays a vital role in affecting η_0. The rapidity of reactions during a converter blow, the fast dephosphorisation reaction in the Perin process, the rapid drop of carbon during vigorous lime boil indicate the combined effects of increased surfaced area as well as increased turbulence. In many metallurgical reactions diffusion is the rate controlling process and in such cases increased fluidity of slag considerably accelerates the reaction velocity. While thermodynamics deal with equilibrium considerations, kinetics tend to avoid these equilibria. In fact the rates of reaction, particularly the rates of slag metal refining processes, depend on the extent to which the slag metal phases are out of equilibrium. In solid-gas reactions (as in the stack of blast furnace) preparation and sizing of raw materials (sintering of ores etc) with a view to increase the surface to bulk ratio considerably increases the reaction velocity and hence the production.

The kinetics of a process is no doubt important but more important is the question of the theoretical possibility of a process. All metallurgical reactions dealing with extraction and refining processes ultimately involve transfer of one or more species of atoms from one phase under a certain set of environments to another phase under another set of environments. If this transfer has to be spontaneous, the movement must be from a higher to a lower potential. As in the case of gravitational potential (ergs/gm) or electrostatic potential (ergs/stc) the change in chemical potential μ in the case of atoms and molecules is defined as the work dw to transfer dn atoms

or,
$$\Delta\mu = \frac{-\Delta W}{\Delta n} = -\frac{\delta G}{\delta n} \quad . \quad . \quad . \qquad (17)$$

where,
$$G = H - TS \quad . \quad . \quad . \quad . \quad . \qquad (18)$$

The Chemical potential has an enthalpy term H and a restriction[3] or the entropy term $(-TS)$—the negative sign implying more disorder or less restriction. Under the same enthalpy, the chemical potential of any atomic species is raised if subjected to greater restrictions be it in the form of greater partial pressure or smaller volume or restrictions involving rotation, vibration of molecules and so on.

Just like electrical potential determines the direction of flow of electricity or temperature (thermal potential) determines the direction of flow of heat but cannot by themselves determine the magnitude of the flow of those quantities, similarly chemical potential determines the direction of flow of matter but does not by itself indicate anything regarding the magnitude of that flow. For this purpose (as Sir Charles F. Goodeve[3] remarks) it is necessary to know the "capacity" of the system, Cp, defined by

$$C_p = \frac{dn}{d\mu} \quad . \quad . \quad . \quad . \quad . \qquad (19)$$

analogous to $C_p = \frac{dQ}{dV}$, in the electrical system, with the exception, however, that while the electrical potential rises linearly with the charge, the chemical potential rises logarithmically with matter according to the well known fundamental relation,

$$\triangle\mu = RT \ln \frac{P_2}{P_1} \quad . \quad . \quad . \quad . \qquad (20)$$

where P_2 and P_1 are the partial pressures. From the definition of activity a and activity coefficient f, one gets

$$\mu = RT \ln a + \mu_0 = RT \ln fc + \mu_0 \quad . \quad . \quad . \qquad (21)$$

where c = concentration and μ_0 is a constant.

For example it is found that the equilibrium vapour presssure of oxygen varies approximately as the square of its concentration.

Therefore $$\mu = 2RT \ln [c] + \mu_0 \quad . \quad . \quad . \quad . \qquad (22)$$

where μ_0 is some constant. Since the amount of oxygen n = Vc

where V = volume of metal and c = concentration of oxygen in the metal. Therefore

$$C_p = \frac{dn}{d\mu} = \frac{\overline{Vdc}}{d\mu} = \frac{Vc}{2RT} = \frac{n}{2RT} \quad . \quad . \qquad (23)$$

There are no theoretical limits to raising the electrical potential of a substance, although on sufficiently raising the electrical potential, there may be leakages of electricity. In the chemical potential however there are well defined limits. At 1600°C the potential of oxygen in FeO for example is about −70 K-cals., at one atmospheric pressure. Adding oxygen into molten iron above this limit leads to the formation FeO. In other words there is a definite leakage[3] at this potential into another phase and the whole iron may be burnt out on blowing. With iron saturated with C the oxygen potential is still lower viz. −130 K. cals. Addition of oxygen beyond this limit leads to CO—the "leakage" now being to the gas phase. As carbon is oxidised its potential in iron decreases and the permissible limit of oxygen potential thereby rises, with the condition that $\mu(o) + \mu(2c) = -130$ K. cal. The potential of carbon at ·01% has been found[3] to be −60 K cals, the value of $\mu(o)$ therefore rises to —70 K. Cals. Thus theory indicates that at one atmosphere and at 1600°C it is difficult to lower the carbon content below ·01% in steel without burning some iron as FeO. Since n = Vc, where c is concentration, one gets by combining (19) and (21)

$$C_p = n\left(\frac{1}{RT} - \frac{1}{f}\,\frac{\delta f}{\delta\mu}\right) \quad . \quad . \quad . \qquad (24)$$

In general therefore the capacity Cp of a system may not increase with n as indicated in (23) but may even decrease with concentration depending on the changes of the activity coefficient with concentration. All factors which tend to make $\frac{df}{d\mu}$ negative tend to increase Cp and hence keep the chemical potential at a low level. These considerations are very helpful in slag-metal reactions. Because an element from the metal phase will tend to flow to the slag phase if its chemical potential is kept lower in the latter. And the chemical potential in the slag-phase can be kept lower if such other elements be added to the slag which will increase its capacitance and thereby keep the potential lower and create a condition favourable for a spontaneous flow of undesirable elements from the metal to the slag phase.

In pyrometallurgical operations slag is the most important phase. In fact the success of smelting and refining depends on the correct mass, composition and temperature of slag. For economic consideration mass of slag per ton of metal has to be kept minimum and this puts additional importance on the correct and careful control of composition and temperature of slag. Considerable volume of work has been done on the thermadynamic studies of slag-metal equilibria based on the molecular nature of slag but considerable evidences exist to show that almost all slags are ionic in nature. Although no genralised treatment of slag thermodynamics based on ionic nature of slag is yet available, attempt has been made in the next section to indicate some fundamentals of the ionic theory of slag proposed by Herasymenko[5-21] and others.[8]

V. IONIC THEORY OF SLAG[5-21]

Quite a large volume of work has been done on the thermodynamics and kinetics of slag-metal reactions.

Many physical properties of slags, particularly their electrical conductivities and viscosities, indicate definitely the existence of charged particles (simple or complex ions).

In this connection the following few facts are noteworthy :—

(i) molten slags display conductivity (ionic type) and other properties to suggest that they consist of simple cations and anions like Ca^{++}, Fe^{++}, Al^{3+}, Si^{4+}, O'', S'' etc and also complex ions like $(SiO_4)''''$ and $(Po_4)'''$. Acid slags particularly silicates due to the formation of complex polymerised anions are more complex than basic slags.

(ii Co-ordination Number—

(a) The average co-ordination number of many ions in the liquid slags remain more or less the same as in the solid state[5, 6].

(b) At high temperatures the co-ordination numbers may change for both solid and molten sillicates—For example the co-ordination number of Ca^{++} at low temperature is 6 in γCa_2SiO_4 but 8 in βCa_2SiO_4 and 10 in αCa_2SiO_4 at higher temperatures.

(c) The tendency of ions to retain a certain co-ordination number may lead to a separation of two immiscible phases[12, 13]

(iii) The properties of molten slags are primarily governed by their ionic sizes and charges. Simple anions are usually larger than simple cations. Complex ions like SiO_4'''' (2·79A) or PO_4''' (2 76A) are much larger than simple ions like O''(1·4A) S''(1·84A) or Ca^{++}(1A), Mn^{++}(·8A), F'(75·A), Mg^{++}(·65A) Fe^{++}(·6A), Al^{3+}(·5A), Si^{4+}(·41A). From purely electrostatic consideration a small size and a large charge induce stability.

(iv) Ideal and non-ideal behaviour—

(a) ions like O'', S'', Mg^{++} etc having electronic structures similar to those of inert gases are comparatively more stable and tend to obey the ideal laws of Mass-action. The activities of such ions are therefore taken equal to their ionic concentrations. For example in basic steel making the sulphur-oxygen equilibrium represented by

$$S + O'' \rightleftharpoons S'' + O$$

was found to be independent of the concentration of slag constituents like O'', SiO_4'''' or Ca^{++} ions. Similarly, data from Winkler and Chipman reveal that in slags saturated with MgO, the product Mg^{++}. O'' was independent of other slag constituents.

(b) ions of small size and large charge are more stable and tend to obey ideal laws better than complex unstable ions.

(c) variations in the activity of simple and small ions of the transition type elements (Fe^{++}, Fe^{3+}, Mn^{++} etc) are one of the causes of their non-ideal behaviour. Studies on the nature of chemical bond reveal (15, 16) that a considerable part of the bond—energy of ionic inorganic substances is due to covalent linkages. In NaCl for example each Na not only attracts the surrounding six Cl ions with coulomb electrostatic forces but also forms simultaneously covalent bonds with them. In liquid slags containing simple and complex ions, the variation in the relative proportions of ionic and covalent forces may be the causes of this non-ideal behaviour.

(v) (a) The heats of formation of salts with complex anions like SiO_4'''' and PO_4''' increases with increase in the ionic radii of the metallic kations. For example Mg^{++}, Fe^{++}, Mn^{++}, Ca^{++} and Ba^{++} with progressively increasing ionic radii have progressively increasing heats of formation of their phosphates. This is helpful in understanding the reason for the large increase in the Phosphorous equilibrium ratio during basic open hearth steel making process when Mg^{++}, Fe^{++} and Mn^{++} are replaced by Ca^{++}. Theory indicates that the dephosphorisation effect of $(Ba)^{++}$ ions would be greater than that of Ca^{++} ions.

(b) larger cations like Ca^{++} tend to diffuse preferentially towards complex anions like PO_4''' and thereby effect outward diffusion of smaller kations like Mg^{++}, Fe^{++}, Mn^{++} away from complex ions. This phenomena also appear to have some relation with the kinetics of dephosphorisation in basic steel making.

VI IONIC NATURE OF MOLTEN ALLOYS[22-32]

In a molten binary alloy the constituents may be present either as atoms or ions or both. It has been found that when a molten alloy is subjected to a D.C. electric field there is preferential segregation of atoms at the cathode and anode. The mechanism of ionisation of atoms in molten alloys may not be similar to that in acqueous electrolytes or for free atoms. But whatever be the mechanism, the charge arise due to interactions of the different atomic species in the liquid alloy. Such interactions are also responsible for the different activities of different atoms in molten alloys.

For a multicomponent system as in complex alloys like alloy steels containing i components (1, 2, 3 . . .), the activity co-efficient f, of a particular component 1 is given by

$$l_n f_1 = l_n f_1^{\circ} + x_1 \frac{\delta l_n f_1}{\delta x_1} + x_2 \frac{\delta l_n f_2}{\delta x_2} + x_3 \frac{\delta l_n f_3}{\delta x_3} + \cdot \cdot \cdot \cdot \cdot \cdot \cdot \qquad (25)$$

where $l_n f_i^0 = 0$, when $f_i^0 = 1$ at infinite dilution, and x_i is the mole fraction of the ith component and the derivatives are taken for the limiting case of zero concentration of all solutes (the higher order terms in a Taylor series being neglected). Wagner has also shown that the following simple relation exists between the effects of component i on j and that of j on i.

$$\frac{\delta l_n f_i}{\delta x_j} = \frac{\delta l_n f_j}{\delta x_i} \quad \dots\dots\dots\dots \quad (26)$$

Chipman[31] for example has found that in molten steel at 1600°C

$$\frac{\delta l_n f_{si}}{\delta N_c} = \frac{\delta l_n f_c}{\delta N_{si}} = 10 \quad \dots\dots\dots\dots \quad (27)$$

where C and Si stands for carbon and silicon respectively in steel. Some values of $\left(\frac{\delta l_n f_i}{\delta x_j}\right)$ for different elements in molten steel at 1600°C are shown in Table I. It may be noted that some values of the parameter are positive while others are negative. Some typical positive effects are those of C, Si, Al and P on sulphur. At any given instant of time each S atom is surrounded by say n.-Fe atoms which share the Fe-S bonding energy. Introduction of C, Si, Al or P leaves less Fe to be bonded to S and thereby raises the activity co-efficient of S. Introduction of Mn however decreases the activity co-efficient of S since Mn-S bonding energy is greater than that of Fe-S. Similarly the bonding energy of Fe-O being less than those of Cr-O or V-O, the values of the parameter with respect to Cr and V on oxygen is negative. The bonding energy of Fe-O being greater than that of Ni-O, the value for Ni on oxygen is positive. Apart from the effects of mutual interactions between different solute ions it is necessary in this connection to consider also the effects of the electrons as pointed out by Wagner.

A general outline of the theory and applications of the ionic nature of molten slag has been indicated before. In view of the ionic nature of molten alloys the equilibrium values for slag-metal reaction may undergo modifications in the light of the discussions indicated above. There is considerable scope for fundamental and also applied research work in this field.

TABLE II. Values of the parameter $\frac{\delta l_n f_i}{\delta N_j}$ for different elements j added to liquid steel containing the elements i (Chipman).[31]

i	Added element j										
	C	Si	S	P	Mn	Al	V	Cr	Cu	Mo	Ni
C	+ 9·8	+10	—	—	−0·5	—	—	−4·3	—	0·8	—
Si	+10	+ 3·4	—	+ 11	0·0	—	—	—	—	—	+1·2
S	+ 6·0	+ 7·6	+130	+ 5·7	−5·7	+ 6·5	—	—	−3·2	—	0·0
O	−27(?)	− 2?	− 3·8	− 100?	0·0	− 1300	−57	−8·8	—	—	+1·2
N	+ 7·0	− 4·5	—	—	—	—	−19	−9·9	—	—	—
H	—	+ 3·16	—	—	—	—	—	—	—	—	—

VII DEVELOPMENT OF NEW ALLOYS—ESTABLISHMENT OF ALLOY STEEL AND FERROALLOY PLANTS[81, 82]

A few basic fundamentals underlying the theory or alloys has been indicated in the previous section. Although considerable work has yet to be done to develop a generalised theory of multi-component alloy systems, the principles underlying the behaviour of many binary and some ternary alloys are fairly well established. Sufficient data in connection with the atomic and/or ionic sizes under a given coordination number, the nature of the crystal structure at different temperatures, the lattice parameter values and allied considerations are available to guide the present generation for the development of new alloys with specific mechanical properties—be it high tensile strength or resistance against corrosion, creep or fatigue—or new alloys with specific electrical and/or magnetic properties. While this country is deficient in the raw materials of many essential metals like Ni, Mo, W etc she is fairly rich in the raw materials of many basic essential metals Fe, Al, Ti, Mn, Mg, Th, Zr, Be etc. What are popularly known in other countries as Heavy weight champions (Alloy steels) Middle weight champions (Ti-alloys) and Light weight champions (Al and Mg alloys), Nature has been rather bountiful to provide this country with raw materials of all the basic metals to develop all these champions in this country with indegeneous materials. Even in the field of development of new alloys for nuclear power which involves problems quite specific of its own, this country, though somewhat deficient in Uranium deposits, is fairly rich in other key materials like Th, Zr, Be etc including many rare earth metals. While the field of development of alloys in the Heavyweight champion group (viz alloy steels) alone is broad enough to engage the attention and efforts of all the metallurgists in the country, there is the necessity for development of also the essential middleweight and light weight champions, there is the necessity of providing other alloys to feed the specific needs of the army, the navy and the airforces and last but not the least there are very special needs of the atomic energy establishment. The magnitude of the problem may well be visualised. While space does not permit discussions in detail it is earnestly suggested that :—

(1) immediate steps be taken for the establishment of alloy steel and Ferroalloy plant in the country within the framework of the second five year plan.

(2) provisions be kept for the establishment of Research and Development wings in each large scale metallurgical plants so that there may be opportunities to investigate further some new knowledge from the laboratories on a pilot plant scale.

(3) (a) A coordinated research scheme for the development of new alloys with particular reference to the indegeneous materials be encouraged in all the existing metallurgical laboratories of the country under the Metal Research Committee of the Council of Scientific and Industrial Research. These may be classified into priority groups like the development of

(i) alloy steels with the purpose of minimising or replacing Ni, Mo and W (some with good mechanical properties some with good resistance against corrosion, creep, fatigue and some with good hot hardness).

(ii) Al alloys with good strength and conductivity.

(iii) Ti alloys with high resistance against corrosion, creep, and fatigue at high temperatures.

(iv) Other alloys with specific properties like electrical and magnetic properties and specific properties demanded by the ordnance factories and industries.

(v) special alloys for nuclear power.

(3) (b) Semi-pilot plant activities for the development of new alloys may be encouraged in the educational institutions not only to provide opportunities to test small scale laboratory data on new alloys but to provide a good background for the training of research personnel.

VIII. SURFACE PHENOMENA[33-40] AND DIFFUSION[41, 66]

Practically all phenomena in solid metals and alloys owe their origin and are affected by

(A) The nature of metallic surfaces (or interfaces).

(B) The nature of movements (diffusion) of atoms and/or ions or groups of atoms or ions on surfaces and/or through interfaces and/or lattices.

(A) Metallic surfaces.

To understand the behaviour of metallic surfaces it is necessary to realise that :—

(1) Solid surfaces, unlike liquid, are not equipotential

(2) Solid surfaces are not homogeneous due to

(a) lack of enough mobility of the surface atoms, (b) different types of linkages, (c) different orientations of small crystal aggregates, (d) presence of atoms and ions in pseudo-lattice structures (leading to areas with widely different activities).

(3) There is a phase boundary potential in the region of the interfaces between two phases which may be due to :—

(a) differences in the rates of escape of positively and negatively charged particles from one phase to another (leading to electrical double layer with opposite charges in the two phases).

(b) preferential adsorption of positively and negatively charged particles (adsorption potential leading to electrical double layer in the same phase).

(c) Orientation of the so-called neutral molecules containing electrical dipoles.

(4) There are at least three distinct and definite potentials (Fig. 5 . . .) viz,—

(a) The Fermi potential E which may be obtained from equation (8)

$$E=\frac{h^2}{8m}\left(\frac{3n'}{\pi v}\right)^{\frac{2}{3}} \qquad \text{. . . . . (28)}$$

(b) The "Work function" W_α is the total work done to pull an electron from within the metal through the double layer and past the "image forces" to a point outside the surface. W_α in the phase α is given by

$$W_\alpha = W_e + W_c \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (29)$$

where W_e = work done against long range electrostatic coulomb forces, = the internal electrostatic potential.

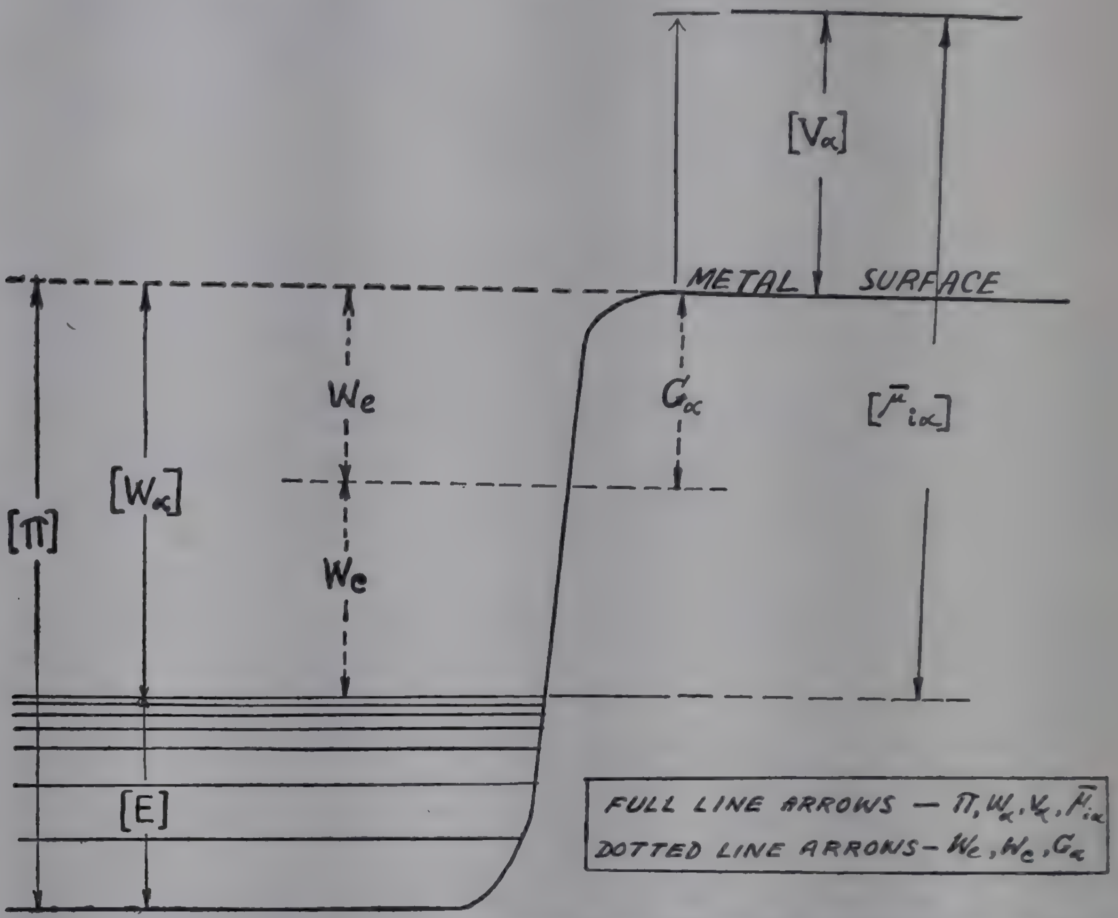

[Vα]
METAL SURFACE
We
Gα
[μ̄iα]
[Wα]
[π]
Wc
[E]
FULL LINE ARROWS — π, Wα, Vα, μ̄iα
DOTTED LINE ARROWS — We, Wc, Gα

FIG. 5. Schematic diagram representing different potentials in metals and alloys. Potentials π, W, $V\alpha$ and $\mu_{i\alpha}$ are definite measurable quantities. Potentials We, Wc and $G\alpha$ are rather uncertain. We and Wc are shown separately for clarity of representation.

and W_c = work done against short range electrical forces (dipole, etc)—called chemical potential.

(c) The external electrostatic or Volta potential V_α is defined as erg/stc at a point just outside the surface.

It may be noted that several other potentials may be expressed in terms of the E, W_α and V_α indicated above. For example,

(i) the mean inner potential $\pi = E + W_\alpha$. This term is useful for electron diffraction considerations.

(ii) the electrochemical potential $\mu_{i\alpha}$ (erg/stc) of a charged particle i in the phase α is given by

$$\mu_{i\alpha} = (W_\alpha + V_\alpha) + \mu_{io} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (30)$$

$\mu_{i\alpha}$ depends both on i and α and is a thermodynamic quantity defined with reference to μ_{io} which is the electrochemical potential of i in a standard phase O in which $(W+V)=0$

Therefore, $$\mu_{i\alpha} - \mu_{io} = W_\alpha + V_\alpha = (W_o + V_\alpha) + W_e \quad . \; . \; . \; . \qquad (31)$$

where ($W_\theta + V_\alpha$) is the sum of internal and external electrostatic potentials and Wc is the chemical potential. Thus electro-chemical potential as the term implies is the sum of electrical and chemical potentials.

(iii) The Galvani potential $G = W_\theta + V_\alpha$

(iv) The contact potential difference between two phases α and β due to flow of electrons owing to their different Fermi levels is given by

$$V_\alpha - V_\beta = W_\beta - W_\alpha \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad (32)$$

This is subject to a small Peltier emf correction due to differences in the concentrations of electrons in the upper Fermi levels when not at absolute zero.

(5) The surface is in a state of strain—both mechanical (leading to surface tension) and electrical due to disturbances in the interaction of valence electrons (leading in some cases to dissociation of adsorbed molecules into atoms or ions). It is well known for example that H_2 and O_2 are adsorbed as atoms or ions and not as molecules in metals and alloys.

(6) when a beam of particles (molecules, atoms, ions or electrons) hit a metallic surface they may be (i) reflected (ii) diffracted (deBrogile effect) and/or (iii) captured. The captured particles are responsible for various types of adsorption phenomena (from physical adsorption to chemisorption) leading to to the formation of different types of films with different electron distributions and causing an additional double layer to form. The work function W_a is increased or decreased depending on whether the negative or the positive side of the double layer is outside the surface. The work function is not only important in thermionic emissions but in electroplating, corrosion, rate of formation of films and allied phenomena.

(7) A "dislocation" near a free surface experiences an image force equivalent to the force which would be produced by a dislocation of opposite sign within the lattice to migrate to the surface and get annihilated with dislocations of opposite sign at the surface.

From what has been indicated before it will be obvious that the behaviour of metallic materials depend considerably on the nature and properties of their surfaces. It has been found[40] for example that specimens of carbon steels charged to a positive or negative potential have different oxidation characteristics from those of a neutral specimen. It is not unlikely that catalysis, metal deposition, nitriding and a host of other surface phenomena may be controlled by different electrostatic potential and/or the electron density (thereby affecting the Fermi potential and/or the work function). There is considerable scope for both fundamental and applied research with respect to metallic surfaces and interfaces.[40]

(B) DIFFUSION

In the field of metallurgy and also other branches of science and engineering the phenomenon of diffusion in solid, liquid and gaseous media play quite an important role not only because it offers a deeper and clearer understanding of the basic mechanisms underlying a large number phenomena (like oxidation, deoxidation carburisation, decarburisation, precipitation, ageing, nitriding, homogenisation, etc.), occuring in metals and alloys but because such understanding often leads to better control of metallurgical processes yielding better products at lower costs.

The following considerations are noteworthy in connection with diffusion of atoms or ions in solid metals and/or alloys.

(1) From Fick's first law of diffusion it is known that the amount of mater dm diffusing through a normal area A in time dt is proportional to the concentration gradient $\delta c/\delta x$

$$dm = -{}_{c}D\frac{\delta c}{\delta x}A\,dt \quad \dots\dots\dots\dots \quad (32a)$$

or,

$$J = \frac{d\mu}{dt} = -{}_{c}D\frac{\delta c}{\delta x} \quad \dots\dots\dots\dots \quad (32b)$$

where ${}_{c}D$ = concentration diffusion co-efficient,

$\mu = m/A$ and J = flux of matter crossing unit area in unit time.

(2) Since different components i of a multicomponent metallic system diffuse at different rates, several diffusion equations are necessary and in general, one may write,—

$$J_i = \sum_q -{}_{c}D_{i1}\frac{\delta c_q}{\delta x} \quad \dots\dots\dots\dots \quad (34)$$

where ${}_{c}D_{i1}$ represents in general concentration diffusion co-efficients of the ith component in a system of q components and depends both on concentration and temperature.

(3) Since diffusion has been found to occur "uphill" that is, from a region at lower concentration to another of higher concentration, the driving force is not concentration gradient $(-\delta c/\delta x$ but the gradient of some-other thermodynamic function like activity, fugacity or chemical potential G. It appears therefore, that in general movements of atoms or ions occur due to the existence of the gradient of some scalar potential function so that one may write in general,—

$$J_i = \sum_q -{}_{x}D_{i1}X_q \quad \dots\dots\dots\dots \quad (35)$$

where X_q is in general the gradient of some scaler function—be it activity, fugacity, chemical potential and so on. (a) If, for example one takes $X_q = -\delta G/\delta x$, where G = Chemical potential = b + kTlnfc

k = Boltzmann constant
T = °Kelvin
f = Activity coefficient
c = concentration.

One gets

$$J = \bar{u}kT\left(1 + \frac{\delta l_n f}{\delta l_n c}\right)\frac{\delta c}{\delta x} \quad \dots\dots\dots\dots \quad (36)$$

where $\bar{u}$ = average velocity per unit force or the "mobility factor".

(b) If one assumes X_q to be the gradient of energy density Ψ where $\Psi = A\phi a$

ϕ = potential of the lattice site in erg/mass
a = activity of ion concerned.
A = constant depending on temperature and stress

conditions,—

One gets[43-45], $J = -\underset{\psi}{DA\phi f}\left(1 + \frac{\delta l_n f}{\delta l_n c}\right)\frac{\delta c}{\delta x}$ . . . . (37)

(4) Different alternative mechanisms of diffusion have been proposed viz.,—

(i) diffusion by direct interchange of atoms (which is rather unlikely)

(ii) interstitial diffusion (which may occur in special cases of small atomic or ionic sizes)

(iii) Vacancy or "hole" mechanism of diffusion (which is more likely)

In each of the three different types of mechanism, the problem has been treated from the points of view of kinetic theory and the reaction rate theory of crossing the potential barrier. If p be the probability/second for an atom to cross the potential barrier of energy E, the different mechanisms of diffusion lead all in general to the relation.

$$\bar{u}kT = = \frac{a^2}{\delta} p. \qquad (38)$$

where a = distance between two equilibrium positions of atoms.
δ = number of available directions of migration.
$p = Be^{-E/kT}$

The factor B stands for a variety of expressions depending on the particular mechanism of diffusion and the particular mode of crossing the potential barrier.

(5) In polycrystalline metals and alloys, atoms or ions may diffuse along three distinctly different types of path, viz., through the crystal lattice, along or through the grain boundary and along surfaces. The first may be termed lattice diffusion and the last two as interfacial or surface diffusion.

(6) D as a function of temperature may be expressed as

$$D = D_0 e^{-Q/kT} \qquad (39)$$

where D_0 is independent of T and ranges in value for different systems from 10^{-9} to 10^4

(7) So far no generalised theory of solid diffusion is available. Nevertheless, the following observations are interesting and helpful :—

(a) In a binary alloy of A and B, the more dissimilar are two components (in terms of solid solubility, melting points, relative positions in the periodic lable, relative atomic or ionic sizes) greater is the value of D.

(b) If the minimum distance of aproach of atoms in A be less than that of atoms in B, then diffusion coefficient of A in B is greater than that of B in A.

(c) Since melting points T_m and sublimation energies E are approximate measures for the energy required to loosen atoms from their lattices and since diffusion of atoms (whatever be the mechanism) implies some loosening of its bonds from its equilibrium position in the lattice, it is quite likely that there may be some fundamental relations between diffusion coefficient D, activation energy Q, T_m and E.

(i) It is found that for transition elements and for metals of the Cu-group (Cu, Ag, Au)

$$\frac{Q}{T_m(\text{Solvent})} \cong 21 \quad \ldots\ldots\ldots \quad (40a)$$

It is also found that

$$\frac{Q}{T_m(\text{Solute})} \cong 20 \quad \ldots\ldots\ldots \quad (40b)$$

(ii) For cubic metals (except γFe) it is found that,

$$\frac{Q}{E} \cong 0{\cdot}64$$

(iii) Q for diffusion of A in B is less than that for self diffusion in B and this difference is more, the more are the dissimilarities between A and B.

(8) Impurity atoms diffuse towards dislocations in a srystal—larger size atoms diffuse towards the tension region around a dislocation while the smaller sizes diffuse towards the compression region—thereby partially releiving the stress and the strain energy around the dislocations.

IX IMPERFECTIONS IN CRYSTALS—DISLOCATIONS[67-68, 70]

A perfect crystal consists of a regular arrangement of atoms or ions which are properly surrounded by neighbours in three dimensions. An imperfection is defined as a small region where the regularity breaks down so that some atoms are not properly surrounded by neighbours. Vacant lattice sites, stacking faults in closepacked lattices, twin boundaries, mosaic structure, crystal fragmentations, interstitial and impurity atoms and dislocations are typical examples of lattice imperfections. Irregularities induced by elastic strains and other distortions which leave the crystal structure clearly recognisable are usually not included as imperfections. Some properties like strength, internal friction and creep rate are highly sensitive to the degree and magnitude of imperfections, while others like elastic constant, resistivity, density and heat capacitance are not so sensitive. While no generalised theory of imperfections has yet been formulated, the theory of dislocations has helped quite a good deal in understanding the mechanism underlying many phenomena in metals and alloys.

X STRESS AND STRAIN IN METALS AND ALLOYS[71-80]

The ultimate object of making shaping and treating metals and alloys is to put them to service where they are subjected to different types of stresses static and/or dynamic. Fundamentally one may recognise a given system of stresses in a material to consist of two parts (i) the so called "volumetric system" which tends to change the size (volume) of the material and (ii) the so-called reduced system which tends to change its shape. It has been found by Bridgman that although hydrostatic pressure has a major effect on fracture it has but little effect on conditions of yield. Yield criteria are therefore primarily governed by the reduced stresses. Mathematically the yield criterion for isotropic materials may be expressed generally as a symmetrical function of the three reduced stresses σ_1, σ_2, and σ_3 and in particular as a function of the three so called invariants J_1, J_2 and J_3 defined as

$$\left.\begin{array}{l} J_1 + J_2 + J_3 = 0 \\ J_2 = \frac{1}{2}(\sigma_1{}^2 + \sigma_2{}^2 + \sigma_3{}^2) \\ J_3 = \frac{1}{3}(\sigma_1{}^3 + \sigma_2{}^3 + \sigma_3{}^3) \end{array}\right\} \quad \ldots\ldots\ldots \quad (41)$$

J_1 being zero by difinition, one is left with only J_2 and J_3. For mathematical simplicity Von Mises and then Hencky proposed $J_2 = 2m$ as the criteria for plastic flow. Tresca on the other hand proposed $\sigma_1 - \sigma_2 = 2m$ as the crieterion for plastic flow. Although physically simpler (and apparantly unsymmetrical) this criterion may also be expressed in terms of the invariants as

$$27\, J_3{}^2 - 4\, J_2\, (J_2{}^2 - 9m^2\, J_2 + 24\, m^4) + 64m^6 = 0 \quad \ldots\ldots \quad (42)$$

It is well known that neither of the above criteria hold good for metals and alloys. The method of treatment of stresses and strains in metals and alloys based on energy consideration (thermodynamic treatment aided with kinetics) and not on energy criterion of flow appear to be more satisfactory. For example if for a unit volume of a material of a given composition and treatment, σ, ε, T, S and α be stress, strain, temperature, entropy and coefficient of expansion and if G_S, G_T, be adiabatic and isothermal modulii of elasticity and t_σ, t_ε be the time of relaxations at constant stress and strain and β be the adiabatic change of temperature per unit strain, a formal thermodynamic approach yields.[74]

$$dT = \frac{Tds}{C_\varepsilon} - \beta d\varepsilon = \frac{Tds}{C_\sigma} - \frac{\beta}{G_S} d\sigma \quad \ldots\ldots\ldots \quad (43)$$

$$\text{and} \qquad \varepsilon = \sigma / G_T + \alpha dt \quad \ldots\ldots\ldots \quad (44)$$

and from kinetic considerations one gets

$$\triangle T = -t_\varepsilon \frac{d}{dt} \int \frac{Tds}{C_\varepsilon} = -t_\sigma \frac{d}{dt} \int \frac{Tds}{C_\sigma} \quad \ldots\ldots \quad (45)$$

It may be noted that equation (44) reduces to the well known Hook's law under isothermal condition. The anelasticity in the thermodynamic equation (44) is due to change of temperature. If there be no change of temperature the anelasticity is brought about by equation (45) with which stress strain relations must be associated with under a given rate of testing. Thus thermodynamics introduces anelasticity through change of temperature and kinetics introduces anelasticity through change of time. It is understandable therefore that the inherent irreversibility associated with some kind of friction in all kinetic phenomena in general and mechanical irreversibility or internal friction (responsible for vibration damping) in the case of cyclic stress-strain processes in particular, is responsible for the anelastic behaviour of metals and alloys, no matter how low be the stress-level.

Another very interesting and useful approach based on kinetics and energy considerations is the Reaction rate theory of flow of metals which yields the relation.

$$r = \left[\frac{2}{3}\,\frac{x}{y}\,\frac{kT}{h}\, e^{-\Delta F/kT}\right] e^{c\alpha x\sigma/kT} \quad \ldots\ldots \quad (46)$$

where r is the strain rate, x is the average distance of jump of unit domains (which are groups of atoms or ions) and y is the distance between domains, k = Boltzmann constant, h = Planck's constant, $\triangle F$ = Free energy of activation, c = stress concentration factor, σ is the tensile stress, α = area of each unit flow. The interesting feature of equation (46) is that the strain rate, does not vanish even though the stress σ be vanishingly small. Thus equation (46) is helpful in explaining some of the creep behaviour of metals and alloys (which cannot be explained on the basis of any of the so-called critical shear stress or strain theories). Energy and energy density considerations appear to be a very fruitful field of approach for investigations in connection with other properties and behaviour of metals and alloys.

XI NUCLEAR METALLURGY

In almost all physiochemical reactions in the field of science and technology it is the outergarb of electrons of the atom that plays the fundamental part. The extremely tiny, dense and positively charged nucleus does not ordinarily come into the picture. With the development of nuclear power it is necessary that one probes not only into the outergarb of electrons but into the structure and behaviour of the nucleus. Not much is known about the nature of nuclear forces and inspite of all the work done so far we are yet in the pre-Newtonian age in connection with the nuclear field. Whatever little is known it appears that the process of emission and re-absorption of the meson cloud is an everpresent essential activity of the proton and the neutron and the mysterious nuclear forces arise from an exchange of meson between nucleons. With the capture of a thermal neutron, the nucleus of U^{235} undergoes fission and liberates tremendous energy. Like a typical exothermic chemical reaction,

$$C + O_2 = CO_2 + 96000 \text{ cals}$$

One may write a typical nuclear reaction

$$_{92}U^{238} + {_0n^1} = {_{41}Cb^{99}} + {_{51}Sb^{136}} + 4\,{_0n^7} + 4{,}760{,}000{,}000{,}000 \text{ cals.}$$

The source of atomic energy to start with is U. India has extensive deposits of Th and by reaction with neutrons, Th^{232} may be controverted to U^{233} and thus sustain the reaction. Alloys with reasonable melting points may be obtained with low melting point metals like Bi, Pb and Sn with high melting point metals like Th and U. Metals for heat exchanger tubes should have good resistance against corrosion and creep and be good conductors. Ferritic or Austenitic stainless steels capable to stand at least 8000 psi at 700°C can easily be developed. High melting point ferrous and/or non-ferrous alloys (like Cu-Ni-W alloys) may be developed for absorbing γ-rays in place of Pb which has a low melting point.

It is not unlikely that better fissile materials may be obtained by alloying with other metals by forming the standard or the so called Dispersion type of alloys. The complex distribution of electrons in the U-atom is an added advantage in this connection because of its capability to act with different valences. Cubic and hexagonal metals deform by slip and/or twining. The crystallographic details of U- twins (due to shears of the first and second order) are different from those of cubic and hexagonal metals. Theory indicates that this may be taken advantage of in shaping the metal.

The effects of radiations on metals with particular reference to their effects on elasticity, creep and corrosion resistance are also very fruitful fields of research. Powder metallurgical work with reference to Zr, Be, Al and Mg alloys with or without O_2 and other nonmetals of low capture cross-section is also another useful field.

Nature has been fairly generous to this country with respect to many of the metal bearing minerals essential for the development of nuclear power. It is very likely that a vigorous national drive may be helpful towards the discovery of deposits of other key raw materials also. Some essential materials may be available from other countries. But research should be directed towards atomic autonomy. Moreover technical "Know-how" in this field is not readily available. This calls for the following essential activities.

(1) Vigorous drive for metallurgical research with reference to reactor problems in general (both fundamental and applied) and a coordinated work in collaboration with different universities and research organisations for solutions of specific reactor problems in particular.

(2) Annual symposium on "Nuclear Power" at some suitable place and time. The "Engineering and Metallurgy" section of this Congress is a very good nucleus to start a chain reaction once the neutron beams of the atomic energy establishment could be captured. No secrecy should unnecessarily be maintained. This may sterilise and damp the initial urge and effort.

(3) Introduction of the fundamentals of nuclear science and technology in the undergraduate courses and Reactor technology in the post graduate curricula with the object of training groups of research personnel at different centres.

The British atomic energy establishment remarked "many of the most urgent of our unsolved problems lie in the field of metallurgy." There could be no question that many of the essential problems for the development of atomic energy in this country also lie in the field of metallurgy. If specific problem have been solved in other countries, granted opportunities and facilities these can be solved in this country also. What is needed is to take up a serious and business like objective attitude on the one hand and to inspire the general body of scientists and engineers for an all out effort and seek the collaboration of the existing talents of the country on the other. Nuclear power development is a collective endeavour, a product of critical exchanges of the view points and imaginations of many minds—a result of concerted efforts in the fields of science, engineering and industry.

XII FUNDAMENTALS OF METALLURGICAL AND ENGINEERING EDUCATION [83-85]

UNDERGRADUATE TRAINING

Metallurgy, as already indicated, is the science and art of extracting metals and adapting them to human uses. Metallurgical training is the art and science of manufacturing young "metal graduates" and adapting them to human uses. No matter how well a metal is made, it is of little use if not given the right shape and conditioned with the right treatment. No matter how well a "metal undergraduate" is made, he is of little use unless given the right shape to fit into the structure of the needs of the country, and also blended with goodness and the warmth of human virtues. In the ultimate analysis there appears to be two aspects of metallurgical education at the undergraduate level.

(A) Firstly, there is the fundamental aspect of converting the raw college material into a young "metal undergraduate".

(B) Secondly, there is the applied aspect of shaping the "metal undergraduate".

During the process (A) emphasis need be laid on

(i) The teaching of the fundamentals of the basic sciences—physics, chemistry and mathematics and engineering subjects like: drawing, electrotechnology etc and their implications with reference to the science of metals and

(ii the training of the young talents in creative thinking with courage and confidence.

During the process (B) the young learner is gradually led into a different arena and trained,

(i) to manipulate his basic knowledge in specific fields of operation, to appreciate the effects of different variables on actual production and unit operation and

(ii) to appreciate human values, to keep alive a burning ambition to build and to help the community and the nation.

Emphasis on the teaching of the fundamentals of the basic science and engineering is essential for various reasons I have indicated in detail elsewhere.[85]

It is often questioned, "Of what use will the laws of thermo-dynamics be to a young metallurgist taking up the career of a smelter in a steel smelting shop?". "Of what use will be mechanism of plastic flow of metals be to one taking up the career of a roller in a rolling mill? Pursuing these lines, it is often suggested that the curriculum may be divided into two different courses—one for those who intend to go to the industries and the other for those taking up research and/or an educational career. While such a division of the course might have been useful several years ago, most of the leaders in the field of metallurgy believe that such a splitting at the cost of the fundamentals is undesirable today. Prof. John Chipman[84] of the Massachusetts Institute of Technology remarks that metallurgists seeking jobs in industries need just as much the "science of metals" as those desiring to become metal-scientists. For example the development of new materials towards self-sufficiency has two basic requirements:

(i) The raw materials of the country, and

(ii) The education and training of the young talents of the country to creative thinking.

And creative thinking certainly gets the right direction by a through understanding of the basic fundamentals.

Last but not the least, the "metal undergraduates" should be given that treatment which makes him a tough alloy steel, ready to stand the tests of service. A tough soldier with a burning ambition to build, with an ardent desire to help the community and the nation. There is no one formula to impart such an education, but the underlying principle is essentially simple, and that is to inspire the young pilot with the fact that it is the force of Hard work and the force of Goodness that ultimately win, the former supplying the "energy" to move and the latter the "direction" of motion. And with enough energy and the correct direction the pilot is sure to land safe at his desired destination.

POST GRADUATE TRAINING

Post graduate training in metallurgical engineering should have essentially two basic objects in view :

(i) To select creative talent and provide for its education and training so that the product is capable of manning research and development projects and the educational institutions.

(ii) To encourage research—with particular emphasis on fundamental research—so that the wealth of our basic knowledge on the science of metals may be increased.

These dual tasks are more or less interwoven with each other. Creative talents grow well in an atmosphere of research and research is fed well by creative talents. Nature unfortunately does not produce many men of creative talents. Nevertheless this country has already demonstrated its worth in fundamental research in many fields of science and it can do so in the field of the science of metals also. For this purpose it is necessary that young men of talent are selected early in the under-graduate level, trained on a higher standard in the under-graduate course, and encouraged to continue their career leading to the Master's and/or Doctor's degree.

XIII. CONCLUDING REMARKS

Within the limited scope of this address I have attempted to glance over a few of the fundamental areas which form the basis of metallurgical research and education. Education and research as you know are mutually complementary—one feeding the other. Educational activities without research is like an ill ventilated closed room without the fragrance and freshness of an envigorating atmosphere, without the warmth and brilliance of a pleasing sun. Research without some educational activities on the other hand is devoid of some features of discipline that helps to broaden one's vision, is devoid of an apparatus and a technique that help to consolidate the very foundation on which research is built and last but not the least is devoid of that human touch and jovial element, that love and enjoyment of teaching and lively discussion which help to refreshen and revitalise the mind and intellect towards a greater dedication for a cause which one would like to sweat and toil for generations, if necessary, without any metallurgical creep or fatigue.

The benefits of research is cumulative to the teacher, the research workers, the students, the institution and last but not the least to the industries. Scientific discoveries and their applications make up a kind of a self propagating chain reaction tending to grow almost indefinitely in speed and intensity. In mathematical language if P stands for progress or profit and R for research, P is almost an exponential function of R. To be interested in profit but not in research defeats its own purpose. On the other hand industrial development backed by research follows an exponential pattern. The growth of iron and steel industries of the world is a typical example. Many instances can be cited where growth and development have been of an exponential nature. The first and most important pre-requisite for cumulative research is an inherent "desire" or the "research outlook" on the part of the research personnel and also on the part of the industries and others responsible to finance and sustain that research. Not only the three M's-"Men" "Money" and "Materials" —but the fourth M the "Mind" is the determining factor practically in every sphere of human activity including progress and research. Men, money and materials are there to form the "nucleus" but nucleus by itself cannot start a chain reaction. It is the "neutron", the "mind" the "inspiration" or should I say the "intoxication"—that does it. The "nucleus" and the "neutron", the "man" and the "mind" once inspired propagate progress by chain reaction.

It is necessary to point out that research is not luxury. In this world, the atomic and the nuclear world, we live in today, research and more research are as vital to the nation as air and water to life. The purification of metals upto one part in a thousand million, special modes of alloying and fabrication under extremely limited conditions to yield simultaneously a combination of large number of sometimes self-conflicting properties for nuclear power projects, development of new alloys for a large variety of civil and defence purposes with particular reference to indegenous materials, the very powerful but highly specialised tools of investigation and research available today demand a definite "reorientation" to put research and education on a firmer and broader foundation. It is well known from the history of evolution, from the science of Palaeontology, that many biological species grew and prospered for a time and then died out. The conditions of survival of man as a biological species and of the growth of his civilisation involve the use of organised knowledge and reason. India shall have to face the world on all fronts today or tomorrow. The condition of our survival then has to be laid to day through the use of organised knowledge, through the creation and use of new knowledge. What could be the surer method of using organised knowledge but to organise a chain of industries? What could be the surer method of creating new knowledge but to create facilities for research? Industries are the sources of energy to the nation. But for an overall growth of a nation mere energy to move is not enough. It needs the direction of motion. Research and education come into the picture not only because of the power of the laboratory but because of the direction of motion they provide. With sufficient energy to move and the correct direction of motion let this nation grow and prosper and play its due role not only to live well by itself but to build a safer and better world for all to live in.

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24th ,,	1937,	Hyderabad	16	8	0
25th ,,	1938,	Calcutta	30	0	0
26th ,,	1939,	Lahore	20	0	0
27th ,,	1940,	Madras	27	6	0
28th ,,	1941,	Banaras	30	4	0
29th ,,	1942,	Baroda	25	8	0
30th ,,	1943,	Calcutta	19	8	0
31st ,,	1944,	Delhi	18	0	0
32nd ,,	1945,	Nagpur	18	4	0
33rd ,,	1946,	Bangalore	21	4	0
34th ,,	1947,	Delhi	23	2	0
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